SOUTH PASS RESOURCES, Inc.

Hydrogeologic Evaluation of Tailings Ponds

Molycorp
Questa Division
Questa, New Mexico

prepared for
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TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

1.0 INTRODUCTION

This report presents an analysis of the hydrogeologic conditions in the vicinity of the Molycorp tailings ponds near Questa, New Mexico. The purpose of this work is to evaluate ground-water flow conditions and water-quality distributions in aquifers that connect impacted water beneath the ponds with discharge areas (such as private wells and the Red River south of the facility). The outcome of the analysis is 1) an explanation of the controlling hydrogeologic parameters; and 2) recommendations for additional work to clarify and extend the hydrogeologic data and for controlling, monitoring, and, if necessary, remediating impacted ground water.

The tailings ponds are located about 1 mile west of Questa, New Mexico (Taos County) and 0.5 mile north of the Red River (Figure 1). Since 1965, tailings slurry has been piped along the Red River from the mill near the Molycorp molybdenum mine, which is located approximately 8 miles east of the tailings disposal sites. The disposal sites currently cover about 550 acres and have been maintained since the mine ceased underground operations in 1992.

History of the Operation

The Questa open-pit mining and tailings disposal operations began in 1965 with the construction of an earth fill starter Dam No. 1 in a large arroyo at the southern end of Section 36. The upstream face of the dam was sealed with the slime faction of the tailings. The water clarification pond was at the dam face. Clarified water was piped via decant structures raised on the upstream dam face, through culvert tunnels under the dam, and then by ditch to the Red River.

Raises and operation of Dam No. 1 continued until 1969 when a second dam (Dam No. 2) was constructed at the north end of Section 36. The clarification pond was then shifted to the north, and the existing decant structures were abandoned for a new overflow weir structure constructed in the bank alongside the new Dam No. 2. Clarified water overflowed the weir and traveled down a decant ditch cut around the west side of Section 35 to a small holding pond called Pope Lake (located at the southern end of Section 35). From Pope Lake, the water flowed over a Parshall flume (later called Outfall 001) and to the Red River.

In 1969, the final 7520-foot and 7525-foot elevation raises on Dam No. 1 were shifted upstream (west) of the existing dam and were constructed on tailings. These lifts were of compacted earthfill.

In 1971, additional tailings storage was created by constructing starter Dam No. 4 in Section 35. This dam and all its subsequent lifts were constructed of earthfill and had internal drain systems. The upstream dam face was also covered with an asphalt or plastic membrane. A decant weir was built to the north of the dam so that the clarification pond could be kept away from the dam face. Clarified water was released over the weir structure into the west ditch to Pope Lake and then to the Red River.

In 1974, east and west diversion ditches were constructed around both tailings storage areas in order to divert all natural drainage away from the impounded tailings. Diverted water re-entered the watershed below Dams 1 and 4.

In 1975, seepage barriers were constructed below Dam No. 1 and to the east of the ridge separating Dam No. 4 and Dam No. 1 areas. These barriers were excavated to clay, sealed on the downstream side, and filled with suitable drain material so that seepage from the tailings storage ponds could be collected and diverted around the dwellings situated downstream of the tailings storage area. This water was then piped to the Red River through Outfall 002.

In 1983, an ion exchange water treatment plant (I-X building) was constructed alongside Pope Lake. This plant processed all tailings decant water before it was discharged into the Red River.

2.0 GEOLOGIC SETTING

The tailings disposal site overlies a series of northeast-trending ridges and washes that have eroded into the sedimentary and volcanic rocks of the Santa Fe Formation. The Santa Fe Formation underlies a lowland bounded on the west by the Guadalupe Mountains and on the east by the Sangre de Cristo Mountains. The Guadalupe Mountains reach elevations just over 8,700 feet and the Sangre de Cristo Mountains just over 10,000 feet. Elevations in the lowland are on the order of 7,000 to 7,600 feet. The Red River, which lies south of the tailings ponds, is entrenched across the Tertiary sedimentary and volcanic rocks creating a gorge southwest of the site. Springs fed by perched or regional ground water occur in the volcanics along the walls of the gorge.

2.1 Regional Geology

Regionally, the site is located within the Rio Grande rift zone, a northeast-/southwest-trending fault-bound structural depression of Mid- to Late-Tertiary age, that extends across New Mexico into southern Colorado. The depression is composed of a number of structural subbasins including the San Luis Basin, which is located at the northern end of the rift. The San Luis Basin is bounded on the east by the Sangre de Cristo Range which was uplifted contemporaneously with the formation of the basin along high-angle normal faults extending parallel to the west front of the range. The basin filled with coarser alluvial sediments along the range front. Farther to the west, the basin fill consists of finer clays and silts deposited in lakes. At the tailings disposal site, the lacustrine (lake) sediments are interbedded with the alluvial sands and gravels. The San Luis Basin fill is assigned to the Santa Fe Formation (Miocene to Early-Pliocene in age) and is believed to be on the order of 15,000 feet thick.

Numerous volcanic fields developed as the result of the rifting and basin formation in Mid- to Late-Tertiary time. The volcanic units that underlie the Guadalupe Mountains along the west side of the site consist of lava flows and ash flow tuffs that range from rhyolite to basalt in composition and that are believed to be Oligocene to Early-Miocene in age (unpublished stratigraphic section, Molycorp files). These volcanics may intertongue with at least the lower Santa Fe Formation. Miocene basalts are intercalated with the Santa Fe Formation. Both the Santa Fe Formation and the older volcanic units are unconformably overlain by the Servilleta Basalt of Pliocene age.

2.2 Site Geology

Stratigraphy

The highly generalized lithologic logs for monitor wells (MW-1, -2, -3, and -4) drilled in 1979 suggested a simple stratigraphy for the site including an upper gravel unit, an underlying yellow clay, and, in one monitor well (MW-1), a volcanic unit beneath gravel (see Figures 2 and

3). Logs of five monitor wells drilled in 1993 show a more complex interlayering of gravel, sand, and clay in the Santa Fe Formation and a wider distribution of the volcanic rocks reported at MW-1. Recent alluvial sediments contain material reworked from the poorly consolidated Santa Fe Formation and appear to be largely confined to the washes. Field reconnaissance, combined with an earlier unpublished geologic map (Vail, 1987) and the borehole data, have demonstrated that two different volcanic units are in the area and that a thin sequence of volcanic sediments, distinct from other Santa Fe units, occurs in a small area south of the face of Dam 4.

Santa Fe Formation

Based on the borehole logs, the Santa Fe Formation in the area of the tailings ponds consists of:

- an Upper Aquifer Unit (UAU) composed of brown sandy gravels and gravelly sands with a subordinate component of pale red brown silty, sandy clay. (Recent sediment was not distinguished from the poorly consolidated UAU during logging);
- a Middle Aquitard Unit (MAU) in which pale red brown clay and gravelly clay are the dominant sediments; and
- a Lower Aquifer Unit (LAU) composed of sandy or clayey gravel. Thin beds of tightly cemented sandstone were noted in MW-7 and MW-10.

These three lithologic divisions are based on dominant textural characteristics, but each unit contains subordinate amounts of the other lithologies (for example: clay beds occur within the UAU and LAU). There are no marker beds to establish lateral equivalence between borehole sections, such that parts of the MAU may be temporally equivalent to the lower part of the UAU, or the upper part of the LAU. In general, the internal structure of a sequence of alluvial or alluvial/lacustrine (lake) sediments is expected to be lensoid in character and have sand and gravel lenses intertongueing and have clay-rich units (Galloway and Hobday, 1983). Borehole logs are presented in Appendix A.

Gravels range from very fine gravel (0.08 to 0.16 inch) to cobble sizes (2.4 to 10.24 inches), but most of the material appears to be below cobble size. Geotechnical drilling for Dam No. 1 (pre-dam cross-section along the proposed axis of Dam No. 1, Molycorp files) indicated boulder size material is present in the UAU. Clast composition in the gravels seems to largely reflect sources in the Sangre de Cristo Range to the east. A variety of volcanic rock types (flows, ash flow tuffs), intrusive igneous rocks (pegmatite, granite, quartz monzonite), and metamorphic rocks (gneisses) occur in the gravels.

A thin sequence of brown, silty highly burrowed sands, black coarsely grained volcanic sands, and gravelly clayey sands outcrop in the vicinity of MW-11. The gravels in this unit are entirely composed of volcanic clasts. Similar sediments were penetrated in the upper 29 feet of MW-11 and in several borings near the toe of Dam No. 4. This unit is shown separately (as T_{sv}) on the geologic map (Figure 2) and is here considered a unit in the Santa Fe Formation.

Volcanic Units

Lithologic information for the volcanic rocks penetrated by the monitor wells comes primarily from cuttings descriptions. The flow rock is a finely crystalline olivine basalt containing brown millimeter-size phenocrysts of altered olivine and of pyroxene (augite?). White phenocrysts of feldspar were also noted. A few cuttings showed glassy textures which probably indicate the tops or bases of individual flows. Both vesicular, and to a greater extent, non-vesicular basalt are present in the section. Flow banding was observed in some cuttings. White and pale blue quartz/chalcedony fills some vesicules and occurs along a few fractures. Thin volcanic breccias consisting of black to gray angular volcanic fragments in a red volcanic matrix are interlayered with the flows. Exposures of the basalt along the walls of Pope Wash, south of MW-11, show that the basalt is highly fractured with sets of vertical fractures coupled with units showing a distinct horizontal parting.

Volcanics observed along the east side of the Guadalupe Mountains were examined during a half-day reconnaissance of the area. These are dominantly medium gray ash flow tuffs characterized by flattened brown to tan pumice fragments and by the presence of black basal vitrophyres. Based on the Questa area volcanic stratigraphy (unpublished section in Molycorp files), and the presence of the basalt unit and the ash flow tuffs unconformably below Santa Fe Formation sediments, it would appear that the basalt is either a tongue within the Santa Fe Formation or belongs to a sequence of older ashflow tuffs and basalts that partly underlie and intertongue with lower Santa Fe. Without further stratigraphic information, such as a lower contact for the basalt (no monitor well penetrates the unit), petrographic data or radiometric age information the stratigraphic position of the basalt can not be completely resolved.

Geologic Structure

Reconnaissance mapping, combined with a description of subsurface geology based on borehole data, indicates the presence of four northeast-trending faults displacing Santa Fe Formation sediments relative to various volcanic units (Figures 4 and 5). The apparent movement along some of the faults is down to the east (a strike-slip component can not be ruled out).

Vail (unpublished geologic map, 1987) mapped a northeast-trending high-angle fault along the east flank of the Guadalupe Mountains. This fault appears to follow the west side of a linear, northeast-trending wash, now largely covered by the tailings behind Dam No. 4. The ash flow tuffs along the east flank of the mountain are moderately tilted along the fault line and in places unconformably overlain by Santa Fe Formation on younger gravels. The Santa Fe volcanic sediments and the basalt unit south of Dam No. 4 lie east of the fault and appear to be truncated by the structure. The ash flow tuffs probably correlate with volcanics that are either equivalent to the lower Santa Fe or older than the Santa Fe and indicate that the fault block to the east has moved relatively downward.

In the Work Plan for the tailings pond facility study (GeoWest Group, 1993), the linear, northeast-trending pattern of the ridge between Dam No. 1 and Dam No. 4 and the wash to the east of the ridge was identified. The wash between MW-1 and MW-2 was postulated to follow a high-angle fault because of the apparent displacement of the volcanic unit in MW-1 relative to the sediments (at the same elevation) in MW-2 (Figures 4 and 5) and because of the linearity of the wash. Wells MW-8 and MW-7, drilled 1,500 feet to the north of MW-1 and MW-2, show a similar structural relationship confirming a linear structure extending northeast along the wash. The volcanics were not encountered in MW-9, drilled to elevations well below the level of the volcanics in MW-1 (Figure 4). However, the volcanic unit does appear at deeper levels farther east in the lower part of Private Well-4 and in MW-10 (Figure 5). The conclusion is that the volcanic unit is offset along a fault that aligns with the wash and that the displacement is down to the east. The eastern block may be slightly tilted to the west.

The cross-sections (Figures 4 and 5) suggest a northeast-trending fault may also extend beneath the ridge that divides Dam No. 1 and Dam No. 4. This structure is based on the difference in elevation between the basalt outcrop immediately east of the I-X building and the top of the volcanic unit in MW-1 (a difference of 157 feet) and the linearity of the ridge. However, at the I-X outcrop, Santa Fe gravels unconformably overlie the basalt, and the basalt ridge could be an erosional feature. The presence of documented faults in the area with the same trend and the linearity of the ridge when coupled with the Tertiary extensional history related to the Rio Grande Rift favors a fault interpretation.

The volcanic sediments outcropping below Dam No. 4 and noted in several boreholes appear to be truncated by the basalt unit unconformably overlain by the Santa Fe Formation immediately east of the I-X building. The volcanic sediments (T_{vs}) were not observed in the exposures of the Santa Fe Formation east of the I-X building. The apparent truncation of the stratigraphic units and the absence of the volcanic sediments are the basis for the fault shown east of the I-X building on the geologic map.

Both the borehole data and the field exposures are concentrated in a narrow band along the front of Dam No. 1 and Dam No. 4. We believe that the structure and the lithologic units, particularly the basalt unit, extend northward beneath the tailings pond facility and southward at least to the Red River. Of hydrogeologic significance is:

1) the extension of the basalt unit in an east-west direction entirely beneath the tailings pond facility at fairly shallow depths; and

2) the northeast-trending structures juxtaposed lithologic units with significantly different hydrogeological properties (for example: clay in fault contact with fractured basalt).

3.0 HYDROGEOLOGY

3.1 Hydrogeologic Units

Part of the Santa Fe Formation can be divided into three sedimentary divisions of hydrogeological significance: the UAU, MAU, and LAU (discussed earlier in Section 2.2 - Stratigraphy; see also borehole logs in Appendix A and Figure 3). Each of these units, plus the volcanic unit, are discussed below. Well construction data is given in Appendix E.

Laboratory measurements of vertical hydraulic conductivity are given in centimeters per second (cm/sec). When these values are converted to gallons per day per square foot (g/d/ft^2), cm/sec is multiplied by a constant of 21220. Horizontal hydraulic conductivity was calculated by dividing transmissivity (derived from pump or recovery test data) by the saturated thickness of the aquifer. The monitor wells do not fully penetrate the aquifers, which results in greater amounts of drawdown and lower calculated transmissivity. Saturated thickness was estimated as the distance between static water level and the bottom of the screen (volcanic aquifer) or the thickness of the confined beds in the case of the LAU at MW-10. The calculations for seepage velocity are in feet/day which, when divided by 86,400 seconds (number of seconds in a day), becomes feet/second. Discharge equals velocity (feet/second) times the cross-sectional area (feet^2) resulting in a flow reported in cubic feet per second (cfs).

Upper Aquifer Unit (UAU)

The UAU is characterized by sandy gravels and gravelly sands, but lenses of clay occur. Wells MW-A, -B, -C, and -9A are screened in the UAU. MW-A (total depth 38 feet) and MW-C (total depth 14.5 feet) commonly have measurable water levels (water-level elevations of 7,282.7 feet and 7,312 feet, respectively). MW-B (total depth 18 feet) was dry in May 1993 but contained measurable water in August 1993 with a water-level elevation of 7,302.77 feet. These three wells are within 100 to 150 feet of each other. Yet the difference in water level-elevations are significant (for example: 20.07 feet between MW-A and MW-B, and 29.3 feet between MW-A and MW-C). Logs of these borings are not available, but the most likely explanation is that these piezometers have intercepted perched zones within the UAU. Evidence of possible perched zones in the UAU include:

- In MW-9A screened from 32 to 42 feet, sandy gravel at 35 feet is underlain by gravelly clays that might have caused perched conditions.

- Air rather than water was used to drill some of the monitor wells in parts of the UAU; field notes commonly reference moist and dry zones at multiple levels in the UAU suggesting possible perched zones.

- Field observations in the area of seepage barrier No. 2 revealed lines of willows or other plants at clay/gravel-sand contacts which are also indicative of perched water.

Although the UAU may be a zone of numerous perched water bodies above a static level in the underlying MAU, at this point, the UAU is not completely characterized. An irregularly shaped water table could occur in the lower UAU, with highs related to preferential discharge areas caused by variations in the alluvial stratigraphy (the elevation of gravelly units underlain by clay) and the distribution of heads beneath the tailings pond. [The term ***head*** refers to elevations of the water-level surface.] Differences in elevation, or head, cause ground water to flow from points of higher total head to lower total head.

Heads throughout the UAU are higher than those in the MAU, LAU, and volcanic unit such that, in all cases, a downward gradient exists. Perched water bodies, developed over lenses of clay in the UAU, contribute to the vertical infiltration of tailings pond water to the MAU. Water infiltrates the clayey sediments (gravelly clays, sandy clays) and also moves beyond the lateral edges of the clay lenses to infiltrate to lower levels. The ephemeral nature of perched zones is probably illustrated by MW-B, which is normally dry but contained measurable water in August. Seasonal or other longer term changes in heads beneath the tailings ponds may cause some zones to be ephemeral.

Middle Aquitard Unit (MAU)

The Middle Aquitard Unit (MAU) consists of interbedded tan to pale red brown sandy/silty clay and gravelly clay with minor lenses of sandy gravels and sands. MW-7A and MW-7B are screened entirely in the MAU. MW-2, MW-3, and MW-4 are screened in the upper MAU, but the upper part of the screened interval may include some UAU sediments. At MW-9, a series of split-tube drive samples (2-inch diameter, 6-inch brass tubes) were collected in the 55- to 56-foot and 85- to 86-foot intervals within the aquitard. The results of the laboratory analyses for vertical hydraulic conductivity, moisture content at saturation (porosity), and grain size distribution are given in Appendix B and are summarized below. The ASTM D 2434-68 fixed wall method was used to find the hydraulic conductivity.

Summary of Laboratory Analyses

Depth (in feet bgs)	Sample Description	Average Vertical Hydraulic Conductivity (cm/sec)	Moisture at Full Saturation (Porosity) (percent)
55.0 to 55.5	Sandy, Clayey, Gravelly Silt	2.25 E-04	18.5
55.5 to 56.0	----	8.26 E-05	22.4
56.0 to 56.5	Sandy, Clayey, Gravelly Silt	3.46 E-02	20.8
85.0 to 85.5	Gravelly, sandy Clayey Silt	2.32 E-03	21.4
85.5 to 86.0	----	4.98 E-07	20.3
Average:		7.4 E-03	20.68

The vertical hydraulic conductivity ranges from 4.98E-07 to 3.46E-02 cm/sec. These values could be lower than the corresponding horizontal hydraulic conductivity by up to at least a factor of 10 (Freeze and Cherry, 1979). If the set of values listed in Table 1 are raised by a factor of 10, the lowest measured value would correspond to a silty clay (Walton, 1988); however, grain size distribution was not determined for this sample. The highest measured value was for a gravelly silt. The hydraulic conductivity value, if raised to E-01, would correspond to a hydraulic conductivity for a silty sand (Walton, 1988). The lower vertical hydraulic conductivities (E-05 to E-07 cm/sec) would be typical of clayey sediment and are the reason the MAU is described as an aquitard. The lense-like character of the MAU and the wide range of vertical hydraulic conductivities indicate that ground water can, given the appropriate head conditions, move down to lower units and that the MAU is a leaky aquitard. These conductivities are sufficient for ground water to move laterally in the MAU.

Lower Aquifer Unit (LAU)

The Lower Aquifer Unit (LAU) consists of interbedded gravelly sand, sandy gravel, and clayey gravel with a lesser component of silt and clay. Three monitor wells are screened in the LAU: MW-7C, MW-9B, and MW-10. The LAU produced very little water during drilling which probably is the result of a significant clay component occurring as matrix and as thin beds in the unit.

An aquifer test (described in Appendix D) was conducted at MW-10 for an estimate of transmissivity. The LAU is a confined aquifer, since the top of the unit is at 86 feet bgs and the water level was at 39 feet. Step tests at 15 and 5 gpm were attempted, but the well pumped dry almost immediately. The test was conducted at a constant rate of 2 gpm for a period of 100 minutes at which time drawdown began to level off at 79 feet bgs. The test had to be stopped before drawdown dropped below pump level.

The constant rate test extended across three log cycles. Applying the Cooper/Jacob Straight Line Method for transmissivity (T) and dividing the T value (9.01 g/d/ft) by saturated thickness (50 feet), the resulting horizontal hydraulic conductivity (Kh) is 0.1802 g/d/ft^2 (8.5E-06 cm/sec). This value would correspond to a clayey fine sand or silt (Walton, 1988). Because the drawdown at MW-10 did not stabilize during the test period, the results from the Cooper-Jacob Straight Line Method cannot be considered accurate.

Another approach to estimating hydraulic conductivity (Kh) is to use the empirical relationship between specific capacity and transmissivity for a confined aquifer (Driscoll, 1986). Specific capacity (Q/S) would equal 0.025 (2/79) and T would equal 50.63 g/d/ft (2,025 x 0.025). The T value divided by saturated thickness (50 feet) results in a Kh value of 1.01 g/d/ft^2 (4.8E-5 cm/sec). This value also corresponds to a clayey fine sand or silt. Again, since maximum drawdown was not reached, the results may not accurately reflect the conductivity of the unit at MW-10. However, the log for MW-10 indicates that clayey gravels and sandy clays make up more than 50 percent of the saturated LAU and, consequently, a low Kh value might be anticipated.

Volcanic Unit

Based on the borehole log for MW-11 and nearby outcrops, the volcanic unit is composed of highly fractured vesicular and non-vesicular basalt. Volcanic breccias and volcanic sediments (at the top of the unit) are a very minor component of the section penetrated by MW-11. During drilling, after static water level was intercepted, the return water was estimated to be in excess of 200 gpm. Medium-grained sand used as a filter pack was carried into the fractures by the strong ground-water flow and ⅜-inch gravel was used instead.

Step, constant rate, and recovery tests were conducted at MW-11 (August 18, 1993). Test results are in Appendix D. Because the 8-inch schedule 80 PVC casing used at MW-11 has an inside diameter of 7.62 inches, the largest pump that could be used had a maximum rate of 660 gpm. A step test of 43 minutes duration at 530 gpm produced 2.21 feet of drawdown. The constant rate test was conducted at 660 gpm for a period of 140 minutes after which drawdown had stabilized. Water level oscillated several feet during the first 15 seconds (well storage effects) before a uniform drawdown curve could be generated. Using the Cooper-Jacobs Straight Line Method and the saturated thickness of the well, a hydraulic conductivity (Kh) of 34,472.9

g/d/ft^2 was calculated. This value is very high, corresponding with the higher Kh values published for permeable basalt flows (E04 to E05 g/d/ft^2) in Freeze and Cherry (1979). The recovery curve using the straight line equation resulted in a calculated Kh of 14,102.56 g/d/ft^2. Recovery tests are generally considered to give better estimates for Kh than pump tests since minor fluctuations in the pump discharge during pumping do not allow a constant rate to be achieved. Specific capacity can also be used to estimate transmissivity and hydraulic conductivity. From the drawdown curve, the maximum drawdown was 2.58 feet. The specific capacity (Q/S) was calculated to be 660/2.58, which is 255.81 g/ft. Using the empirical equation Q/S = T/1500 for an unconfined aquifer, T = 383,715.0 g/d/ft and Kh = T/b (b is the saturated thickness, 56.16 feet), which results in a Kh of 6,832.53 g/d/ft^2. The results from the specific capacity and recovery test gave horizontal hydraulic conductivities that range from 6,833 to 14,102 g/d/ft^2, which is well within published values for permeable basalts.

3.2 Flow Directions and Hydraulic Gradients

Because the Upper Aquifer Unit is likely characterized by several perched water zones, a distinct static water-level surface could not be recognized. Water levels for all of the wells screened only in the UAU were higher than water levels in the MAU, LAU, and volcanic units, thus indicating a downward gradient.

Flow direction and lateral hydraulic gradient for the MAU was based on solving a three-point problem based on water-level elevations in MW-7A, MW-2, and MW-3. Water levels for MW-2 and MW-3 may not be entirely representative of MAU levels because the 1979 logs show the screens extending across a gravel/clay contact. From comparison with the more detailed log of MW-9 (close to both wells), it appears that the top of the screens may include the lower 5 feet of the UAU at best. The flow direction for the MAU is S47°W with a hydraulic gradient of 0.02 foot/foot. The vertical hydraulic gradient within the MAU is downward and fairly steep at 0.97 foot/foot between MW-7A and MW-7B (head is 25.8 feet and the mid-screen to mid-screen length is 26.6 feet). The vertical gradient between the upper part of the MAU (MW-7A) and the LAU (MW-7C) is downward at 0.33 foot/foot. With respect to the lower MAU (MW-7B) and the LAU (MW-7C), the vertical gradient is upward -- indicating the LAU is either confined or within a regional ground-water discharge zone.

In the case of the Lower Aquifer Unit, using water-level elevations for MW-7, MW-9, and MW-10, the flow direction is S6°W at a hydraulic gradient of 0.026 foot/foot. Water-level elevations at MW-7B, MW-7C, and at MW-10 with respect to the adjacent MW-4 show upward gradients -- indicating the LAU is a confined aquifer or is in a ground-water discharge area. MW-9B is screened in the LAU and the water level is near the bottom of the screen at 142 feet bgs. Prior to well construction, the water level was slightly higher (130 feet bgs) and the well water was described as very muddy. It is possible that because of the presence of clay in the LAU, the lower screen has been partially plugged by clay/silt forced into the well bore during development causing the low water level. The pre-construction water level at MW-9B was used to evaluate flow direction and gradient for the LAU.

Water-level elevations at MW-1, MW-8 and MW-11 were used to calculate a flow direction of S55°W and a hydraulic gradient of 0.029 foot/foot for the basalt aquifer. The southwesterly flow direction is similar to the regional flow directions reported by Dames and Moore, 1986. The water level used for MW-8 was measured at the completion of well construction and has not been confirmed by later measurements (due to partial collapse of the casing at a depth of 40 feet; the drilling contractor is scheduled to repair the well in September). The calculated gradient here is an order of magnitude higher than those reported from the Guadalupe Mountain study, but is probably caused by proximity to discharge along the Red River.

3.3 Seepage Velocity and Unit Discharge

Seepage velocity can be calculated from the equation

$$Vs = \frac{KI}{7.48\ ne}$$

where K = hydraulic conductivity,
I = hydraulic gradient,
ne = effective porosity,
7.48 = a constant that converts the result to feet/day when K is in $g/d/ft^2$

For the Lower Aquifer Unit, the hydraulic conductivity ranges from 0.1802 to 1.01 $g/d/ft^2$, the hydraulic gradient is 0.026 foot/foot, and the porosity was estimated at 20 percent. The seepage velocity as a function of the range in hydraulic conductivity ranges from 0.003 foot/day (3.5E-08 feet/second) to 0.018 foot/day (2.08E-07 feet/second).

The rate of flow through a LAU cross-section 50 feet thick and 100 feet in length (5,000 ft^2) can be calculated from the equation Q = VA, where V is the seepage velocity, A is the cross-sectional area, and Q is the discharge. Discharge ranges from 1.74E-04 to 1.04E-03 cfs for this LAU cross-section. Because of the high clay content in the upper LAU, it is likely that similar discharges could be calculated for parts of the MAU.

In the case of the basalt aquifer in the vicinity of MW-11, the seepage velocity ranges from 0.001 to 0.003 feet/second based on the hydraulic conductivities (6,832.53 and 14,102 $g/d/ft^2$), an hydraulic gradient of 0.029 foot/foot, and an effective porosity of 25 percent.

Effective porosity for permeable basalts range from 10 percent to over 50 percent. The 25 percent value is sufficiently conservative given the highly fractured state of the unit. Discharge through a 50-foot thick by 100-foot long cross-section of basalt ranges from 5 cfs at the lower seepage velocity to 15 cfs at the higher one.

3.4 Dilution Effects

An estimate of the effect of the high rate of underflow in the basalt unit with respect to downward moving ground water in the LAU impacted by tailings pond leachate can be calculated using seepage velocities and a mixing equation. Vertical seepage in the LAU will be largely controlled by the scattered clay units. Using the lowest and the average vertical hydraulic conductivity (0.011 and 1.569E+02 g/d/ft^2) from the laboratory results for the MAU (which contains similar lithologies) and a downward vertical gradient between MW-7A (MAU) and MW-7C (LAU) of 0.33 foot/foot, a range of vertical seepage velocity can be calculated. Porosity was estimated to be 20 percent.

$$Vs = \frac{KI}{7.48\ ne}$$

Seepage velocity ranges from 2.8 E-08 to 4.006 E-04 feet/second.

Vertical discharge from the LAU along a 10,000 ft^2 surface at the top of the basalt ranges from 2.71E-04 cfs to 4.006 cfs (Q = VA).

The dilution effect of the underflow in the basalt on ground water discharging from the LAU can be calculated from a mixing formula using the following equation:

$$Cm = \frac{(Cb\ Qb) + (C_{LA}\ Q_{LA})}{Qb + Q_{LA}}$$

where Cm = concentration in underflow due to mixing.

Cb = sulfate (SO_4) concentration in ground water from the basalt (MW-11 = 78 mg/L).

Qb = discharge through a 50-foot thick by 100-foot long cross-section of basalt.

C_{LA} = sulfate concentration (MW-7C = 613 mg/L) in the LAU.

Q_{LA} = vertical discharge over a 10,000 ft^2 surface (100 feet by 100 feet).

Using the range of discharges calculated for the LAU (Q_{LA}), the resulting sulfate concentration in the underflow through the basalt would range from 43.32 mg/L to 315.98 mg/L. These results suggest that underflow in the volcanic unit can dilute LAU seepage to concentrations well below State standards.

Since the Red River cuts through the Santa Fe Formation east of Questa Springs, the mixing equation was used to estimate the dilution effect of the Red River flow on a discharge from the LAU. Unpublished results from a 1993 study of the Red River by Vail Engineering gave a flow rate for the Red River above Questa Springs of 31.4 cfs and a sulfate concentration of 141 mg/L. Using the higher discharge from the LAU calculations (1.04E-03 cfs) and a sulphate concentration of 613 mg/L (MW-7C), the resulting mixing concentration would be 141.00 mg/L. Ground water discharging from the LAU into the Red River at the elevated sulfate concentration would have no effect on the water quality of the river. Discharge from the MAU would be in the same range as the upper LAU and similar dilution effects would be anticipated.

3.5 Chemistry

This discussion of the ground water chemistry is based on the analytic results of monitor well water samples collected as split samples with the New Mexico Environmental Department on August 17 and 18, 1993. The results of the chemical analyses are presented in Appendix C, Plate C-1. Additional chemistry data from documents in Molycorp files or from other consultants' reports are also presented in this discussion.

Plate C-2 shows a series of STIFF diagrams comparing the ground-water chemistry of the monitoring wells. MW-10, MW-11, and MW-CH belong to a different set of water quality measurements than the rest of the monitoring wells. Wells MW-10 and MW-11, which are located down-gradient from the tailings ponds, produce high quality water and are characterized by low Total Dissolved Solids (TDS) and low sulphate content. Water from these wells is of higher quality than a recently (April 1993) collected water sample form the Red River upstream of Questa Springs which showed a TDS at 268 mg/L and sulphate at 141 mg/L. The third well of this group is the change house well (MW-CH) which appears to be screened in the MAU and LAU (based on depth of the perforated intervals; no lithologic log is available). This well has a slightly higher TDS, a lower sulphate, and a higher sodium, potassium, and bicarbonate content compared to all of the other wells. MW-CH is located east of the tailings pond behind Dam No. 1 and, based on flow directions for the MAU and LAU, may be indicative of some of the upgradient water chemistry. The water chemistry at the remaining monitoring wells can be characterized as a high TDS, calcium-sulphate water.

The principal components of the tailings pond leachate that exceed New Mexico State Standards are Total Dissolved Solids (TDS) and sulphate (Appendix C, Plates C-1 and C-2). The higher concentrations of TDS and sulphate occur in wells located east of Dam No. 4 and south and east of Dam No. 1 (see Figure 7). TDS and sulphate concentrations are high in the UAU and MAU units over the same area. Significantly, concentrations are lower in the LAU (MW-7C and MW-10) where the LAU (based on head relationships) appears to be a confined aquifer or part of a regional ground-water discharge zone. A conductivity measurement at MW-9B (LAU) gave a reading of 230 micromhos (08/18/93) similar to the measurement at MW-10 (240 micromhos) where the TDS and sulphate values are quite low. Although the head relationship between the MAU and the LAU are unknown at MW-9, the hydraulic gradient may be upward here as well (based on the low conductivity reading). The water sample at MW-9B was described as very muddy, so the reliability of the conductivity measurement is questionable.

The water-level surface within the tailings pond material (Molycorp data) slopes southward toward the Dam No. 1 at a hydraulic gradient of 0.22 foot/foot, significantly steeper than gradients within the Santa Fe units. MW-7C (LAU) has elevated concentrations of TDS and sulfate, compared to other LAU wells to the south of Dam No. 1. This condition suggests that heads in the UAU and MAU beneath the tailings ponds are higher than those in the underlying LAU and that some leachate-impacted ground water moves down into the LAU. Below the ponds, the bulk of the downward-moving leachate may be concentrated in perched zones within the UAU and may migrate south and west in the MAU. From the toe of the Dam No. 1 southward, the heads are such that the vertical gradient is upward between the LAU and the higher units and the TDS and sulfate remain concentrated in the UAU/MAU. With southward flow, TDS and sulfate are attenuated in the confined LAU, and monitor wells intercepting this unit have low concentrations of TDS and sulfate. The elevated concentrations of TDS and sulfate southeast of Dam No. 1 in MW-4 (UAU/MAU well) are likely caused by the head build up behind the east-trending ridge between the pond and MW-4.

Plate C-3 illustrates a series of histograms showing changes in TDS and sulfate for the period 1988 to 1993, for MW-1 through -4 and for MW-A, -B, and -C. Except for a decline in these components at MW-1, the changes at MW-2, -3, and -4 seem to fluctuate. This fluctuation may be a function of head changes in the pond area possibly related to year-to-year variations in natural recharge from melting snow. In contrast, MW-A and MW-C show a trend of increasing concentration with time. These increases occur in the shallow UAU, in wells constructed near the toe of Dam No. 1. The rising concentration may also result from changes in head. If the head within the pond material declines with time because no new tailings are accumulating, then residence time for the water within the pond sediment increases and concentrations may rise. Shallow wells near the toe of the dam would be particularly responsive to such changes.

South of Dam No. 4, the basalt aquifer, which has a high rate of underflow (see Section 3.4), lies at a shallow level beneath the tailings pond. The water sample from this well shows very low concentrations of TDS (267 mg/L) and sulfate (78 mg/L). This sulphate concentration is lower than that in the Red River north of Questa Springs (141 mg/L) according to unpublished data from Vail Engineering (1993). If tailings leachate is moving down into the basalt aquifer, it is rapidly diluted by the southwesterly underflow in the basalt and the monitor well near the toe of the dam produces high quality water (for example, see STIFF diagram, Plate C-2).

Southeast of Dam No. 4, MW-1 is screened in the volcanic unit. This well has slightly elevated TDS (1,051 mg/L) and sulfate (540 mg/L) with respect to State standards. Head relationships between the volcanic unit and the overlying sediments are unknown here and it is possible that water from the overlying units has moved down into the aquifer. However the heads in the sedimentary section above the basalt at MW-8 was lower (132 feet bgs) than the head in the screened basalt (105 feet bgs) at the time of well construction. The water-level elevation for the basalt can not be confirmed until after MW-8 is repaired. If these head relationships are correct, this would indicate the basalt is confined east of Dam No. 4 and leachate-impacted water would be derived from upgradient sources where higher heads in the sediments might cause a downward gradient. It is also possible that, since flow in the MAU is to the southwest, some ground water having high TDS/sulfate concentrations might move across the fault zone into the basalt. Farther to the west, the normal underflow in the basalt is able to dilute tailings pond concentrations. Once MW-8 is repaired, water level and water quality can be measured and further clarification of the ground-water movement in this area may be possible.

There is some evidence that the fault east of MW-1 may exert some control on the movement of ground water toward the Red River. If this fault is projected to the river, it would approximately correspond to the Questa Springs area and the springs may be directly related to the structure. Water from Questa Springs is piped to the fish hatchery (approximately 4.5 downstream from the springs). This water has a TDS of 173 mg/L and a sulphate concentration of 80 mg/L (Vail Engineering data, 1993). These concentrations are comparable with LAU or volcanic aquifer water. It is possible that, with the southerly flow direction in the LAU, there is a component of flow parallel to the structure. The temperature of this water (8.3°C) is perhaps more compatible with shallow ground water than the temperature (16°C) of the deeper flow system in the volcanics (Vail Engineering data, 1993).

The deeper private wells (P-4 and P-5) south of the tailings ponds have good quality water in terms of TDS and sulfate. Although the P-4 data are fairly old (1988), TDS was 270 mg/L and sulfate was 88 mg/L. Well P-4 is a deep well (175 bgs), is partly screened in the volcanic unit, and is partly in the overlying sedimentary material. Well P-5 is 131 feet deep, which is enough to be into the LAU (perforated interval unknown). The TDS concentration for P-5 is 270 mg/L and sulphate is 112 mg/L (09/15/93). The high concentrations of TDS and sulfate in the shallower wells (67 to 90 feet bgs) may result from these wells being largely screened in the UAU and MAU. Existing logs for these wells are too generalized to be certain of the stratigraphy south of the monitor wells.

3.6 Summary of Hydrogeology

The major points derived from the analyses of the hydrogeological conditions in the area of the tailings ponds are:

- Underflow of high quality water in the regional volcanic aquifer that extends beneath the site appears, through dilution, to reduce the highest concentrations of pond-related TDS and sulfate in ground water from the LAU to levels well below State standards.

- Ground water that flows to the Red River from the MAU or LAU moves with sufficiently low seepage velocity and resulting low discharges that dilution is accomplished by the large flows that move through the channel of the river.

- Ground water from the LAU may be diverted toward the river along a hydrogeological boundary created by the fault east of MW-1 and appears to reach the surface at Questa Springs. Questa Springs water is a cold, low TDS/low sulphate water that is closer in chemistry to the LAU or possibly the deeper volcanic aquifer water (if there is an upward gradient along the fault) than to the MAU or LAU ground water.

- The bulk of the pond-related ground water is concentrated in the UAU and MAU. Concentrations of TDS and sulphate are affected by proximity to the tailings ponds, particularly Dam No. 1, and to heads developed within the tailings pond material and the underlying hydrogeological units.

- The LAU contains high quality water except near the toe of Dam No. 1. From the dam northward, heads may build up in the overlying units such that leachate may move down into the LAU. South of the dam, decreasing heads in the UAU and MAU and upward hydraulic gradient conditions in the LAU (higher heads relative to the overlying units) may result in no downward movement of pond-related water to the LAU.

- The deeper private wells (P4 and P5) are screened partly in the LAU and the volcanic unit and produce good quality water. The shallower private wells (less than 100 feet bgs) appeared to be screened mainly in the MAU or UAU. These wells have the high concentrations of TDS and sulfate.

4.0 RECOMMENDATIONS

Several responses may be implemented for further investigation and remediation of ground water containing TDS and sulfate concentrations associated with leachate from the tailings ponds. These responses fall into two categories: 1) intercepting and extracting seepage and ground water containing high levels of TDS and sulfate; and 2) monitoring the water quality to ascertain any changes in input as well as extraction processes. Although the water quality issues addressed in this report have focused on TDS and sulfate, the extraction of ground water having high levels of TDS and sulfate will also lead to reduction in other components that exceed State standards (for example: Molybdenum at MW-2 and MW-C; manganese at MW-2, MW-C, and MW-10; and fluoride at MW-C). Recommended responses to the issues addressed in the report are:

- Extract seepage waters in the UAU by expanding seepage barrier No. 2 system west of MW-1.

- Construct a line of wellpoints by auger drilling to a depth of 15 feet along an east-west line south of MW-2 to extract seepage from the UAU. The volume of seepage extracted will be used to evaluate feasibility of a seepage barrier or grout curtain.

- Site and construct four extraction wells (Figure 8) to remove impacted ground water primarily from the MAU. These wells would be sited within the current Molycorp property boundary. Extraction Well No. 1 would be constructed northwest of MW-1 and downgradient from the seepage barrier No. 2. Extraction Well No. 2 would be located northeast of MW-7. Extraction Well No. 3 would be located northeast of MW-2. Extraction Well No. 4 would be located just up slope from MW-4. Extractions Wells 2 and 3 might be more effective if they were located southwest of their plotted position. This relocation would depend on access or availability of the parcel of private land between MW-1 and MW-2. Extraction wells in this private parcel of land would require a downgradient monitor well with piezometers in the UAU, MAU, and LAU to monitor water quality changes.

- Prior to the construction of any of the proposed extraction wells, a pump would be placed in MW-4 to test the response of the MAU to pumping at different rates. Discharge from MW-4 will be transported in a tanker truck and disposed of through Outfall 002.

- Because the MAU is dominated by clay-rich units and contains only minor sandy gravel beds, constructing an effective extraction well will require drilling an initial test well at Site 2 or 3 (see Figure 8). The test hole would be used to evaluate whether a well screened in water-bearing zones within the MAU would create a capture zone or cone of depression that effectively extracted MAU ground water. It may be necessary to consider screens in the LAU, which might more effectively dewater the MAU and extract high TDS/sulfate ground water. Because there is an upward gradient from the LAU to the MAU, pumping in the LAU should not cause degradation of the LAU, particularly if the extent of the dewatered zone is maintained within the MAU by controlling the pumping rate. If the LAU is used in this manner, it should be drilled to a depth greater than the existing monitor wells in order to get beyond the clay-bearing zone at the top of the unit.

- Water recovered from the extraction wells would either be added to the 002 Outfall system (if it did not exceed NPDES requirements), or it would be pumped to Dam 5A along the west side of the Dam No. 4 complex.

- A deep (approximately 400 feet bgs) test hole should be drilled along the ridge between Dam No. 1 and MW-4. The purpose of the borehole would be to:

  1) evaluate heads or water-level surface elevations for the three hydrogeologic units versus heads in the pond area and heads down-gradient of the test hole;

  2) define high TDS/sulfate producing zones using geophysical logging (for example, resistivity logs); and

  3) evaluate the stratigraphic section through both lithologic and geophysical logging.

- Continue to monitor water levels and water quality on a semi-annual basis. The purpose of the monitoring is to evaluate any changes in water chemistry related to head changes in the tailings pond area and to evaluate the effectiveness of the extraction system. Key sites along the Red River, in particular Questa Springs, should be part of this monitoring program. The results of the monitoring program should be reviewed on a semi-annual basis to evaluate the need for additional monitoring or extraction wells.

5.0 REFERENCES

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REPORT DISTRIBUTION

Report Title: Hydrogeologic Evaluation of Tailings Ponds

Date: September 23, 1993

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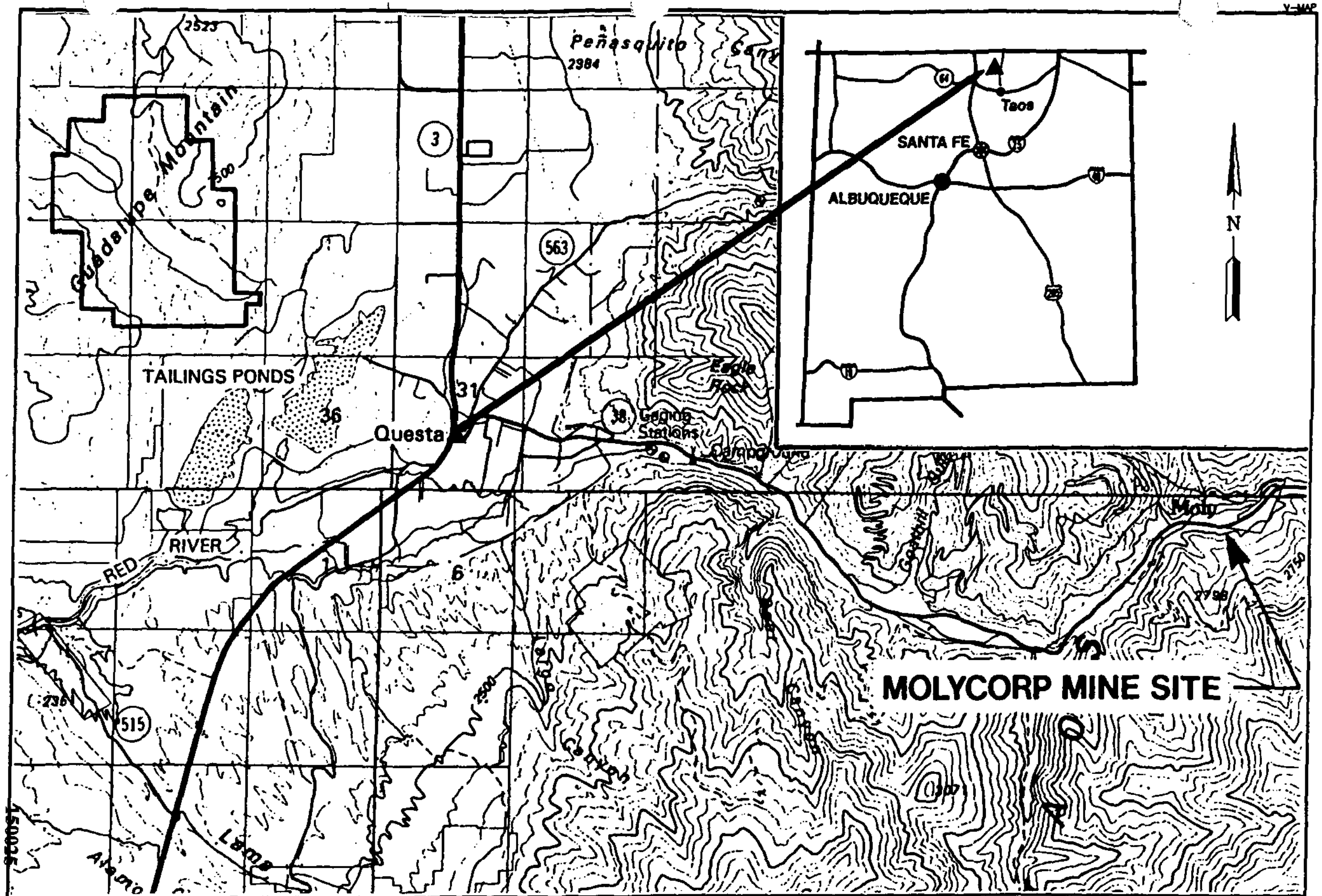

FIGURE: 1

The GeoWest Group Inc.

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001-02	5-25-93	JCK	M.O'M.

LOCATION MAP
Molycorp, Inc.
Questa, New Mexico

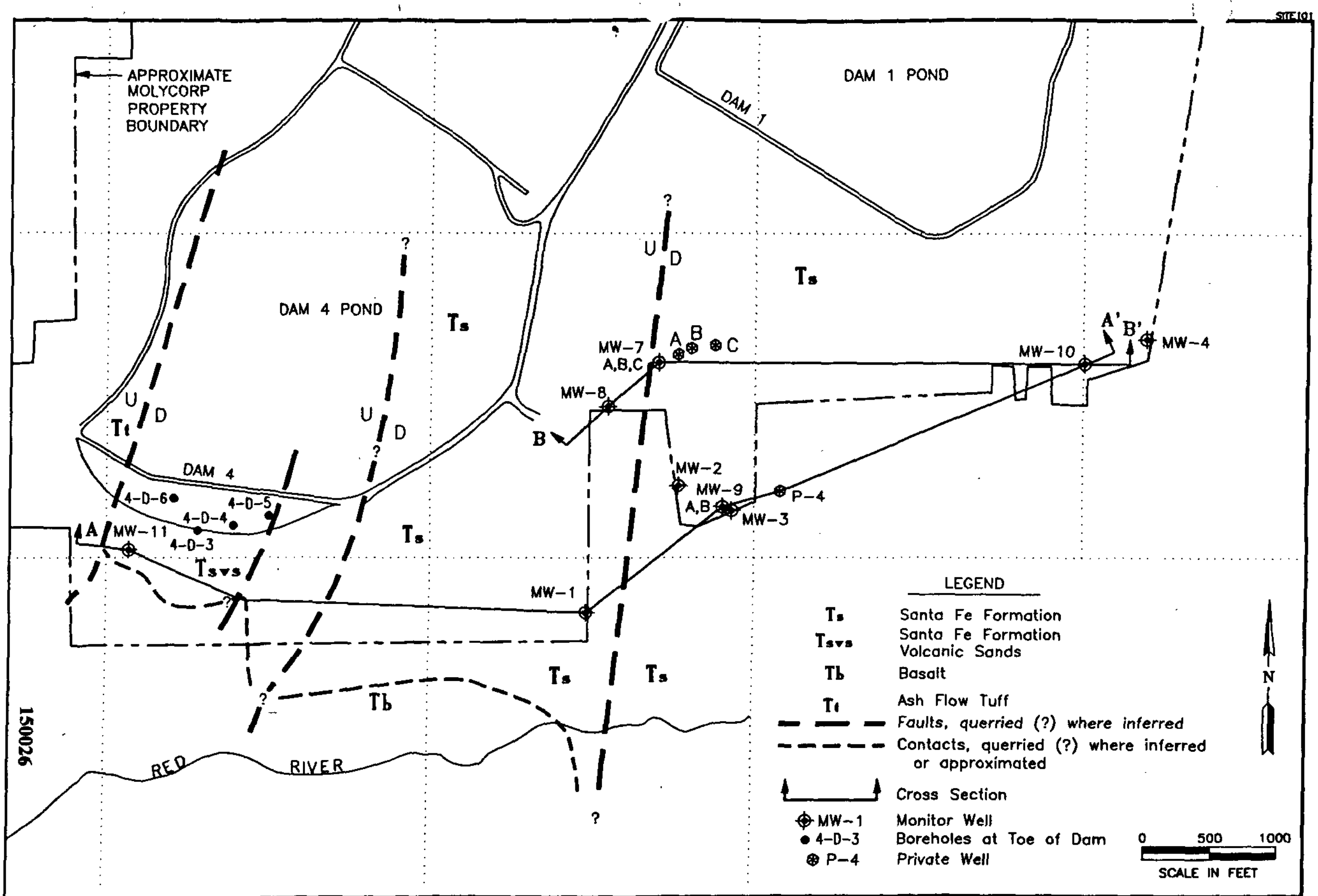
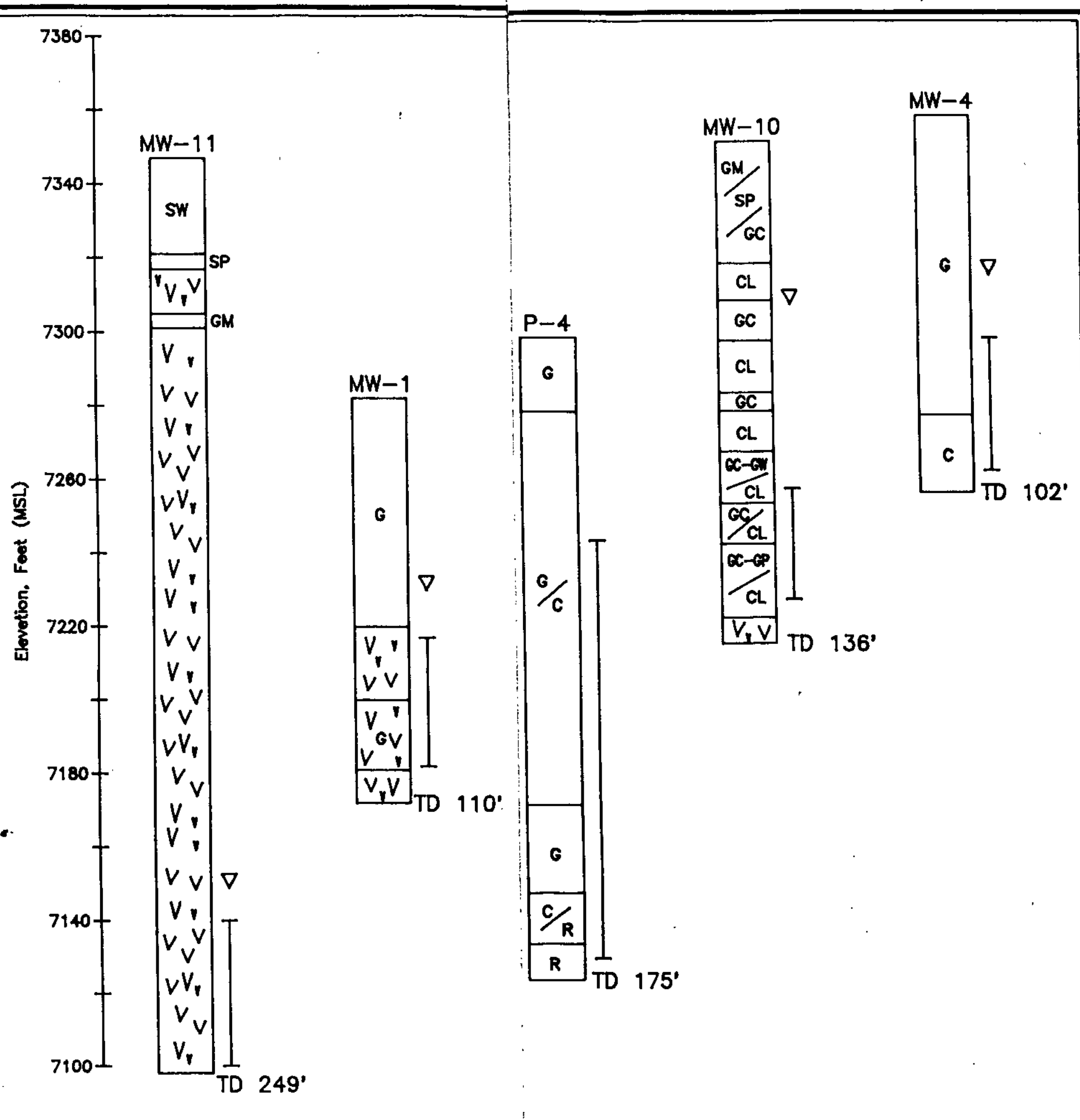


FIGURE: 2	SOUTH PASS RESOURCES, Inc.				GEOLOGIC MAP – TAILINGS PONDS AREA Molycorp, Inc. Questa, New Mexico
	PROJECT No.: 001-02	DATE: 9-20-93	AUTHOR:	DRAWN BY: M.O'M.	

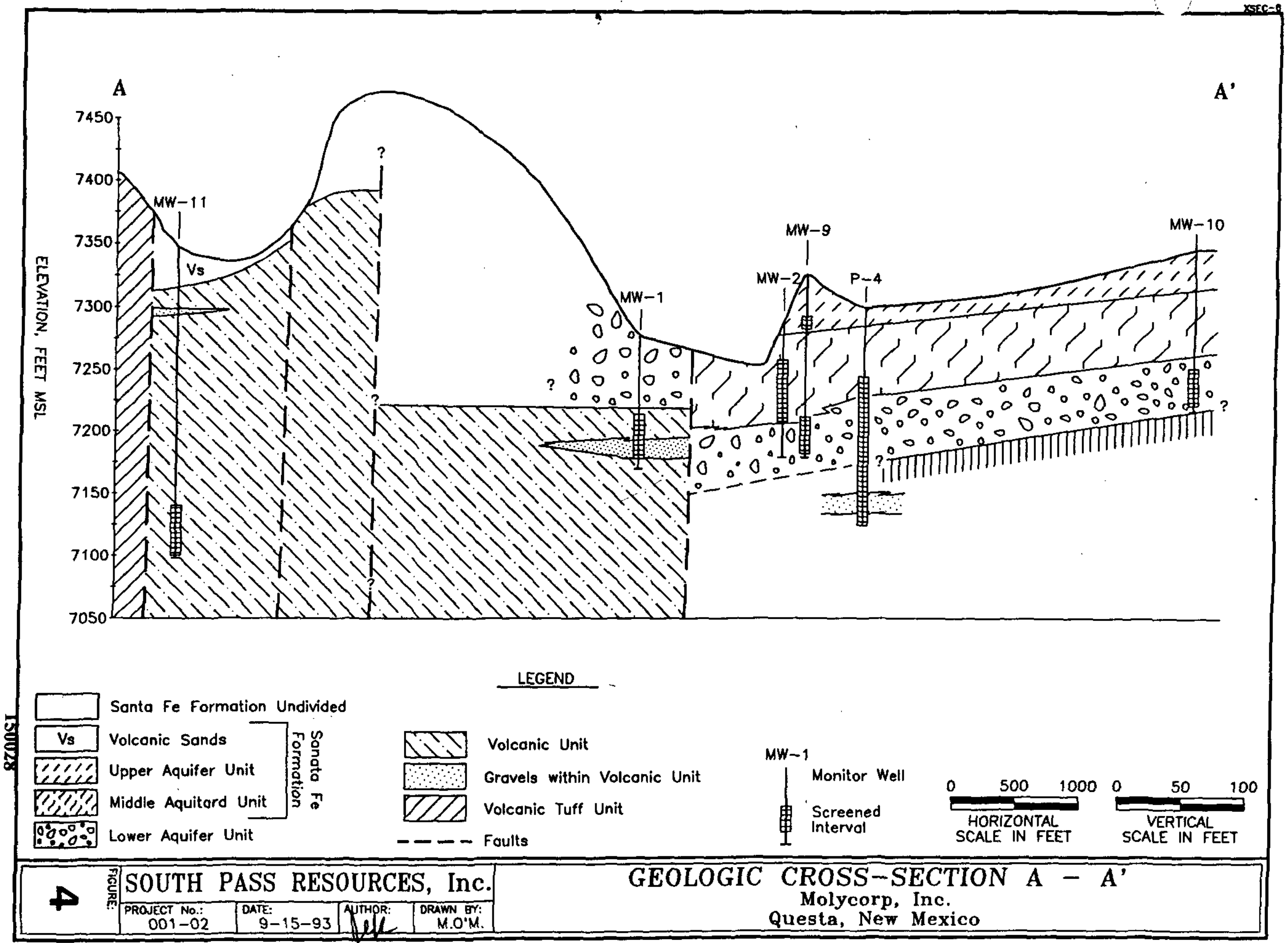


150027

CL	Silty Clays, Sandy Clays Gravelly Clays	SM	
		SP	
GC	Clayey Gravel		
GM	Sandy Gravel	SW	
GP	Poorly Graded Gravels (narrow size range) less than 5% Fines	GM/CL	
GW	Well Graded Gravels (wide range if sizes) less than 5% Fines		

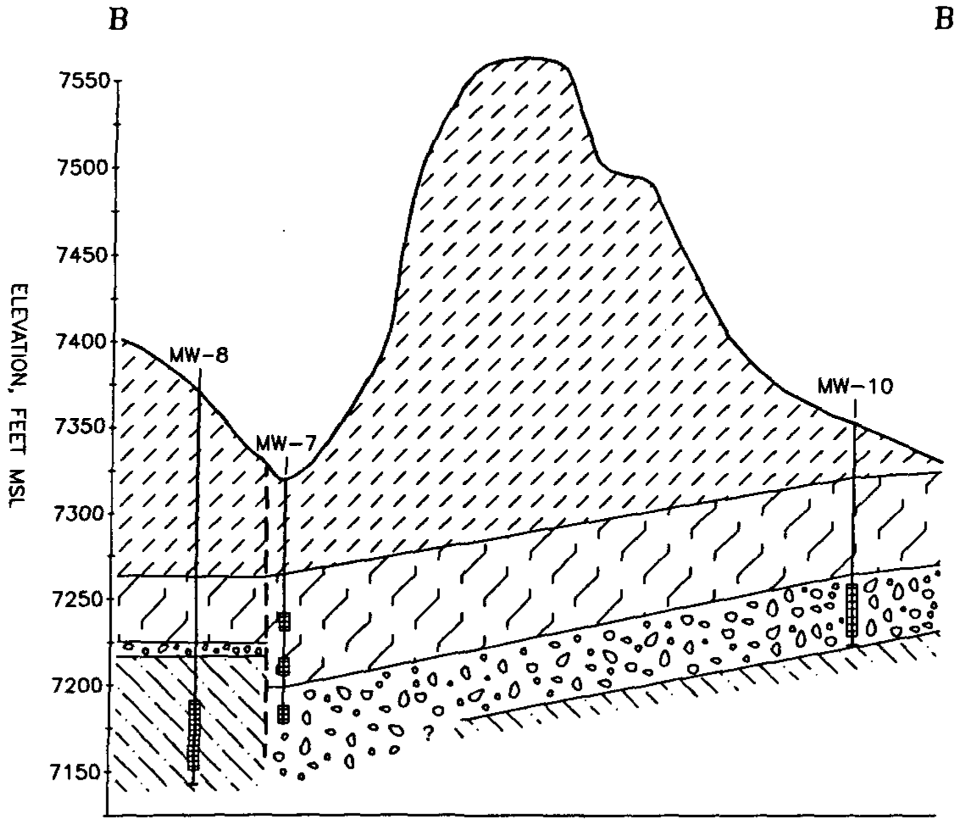
BOREHOLE STATIGRAPHY
TAILINGS PONDS AREA
Molycorp, Inc.
Questa, New Mexico

SOUTH PASS RESOURCES, Inc.				FIGURE: 3
PROJECT NO.: 001-02	DATE: 9-20-93	AUTHOR: JLK	DRAWN BY: M.O'M.	



150028

000313



LEGEND

Upper Aquifer Unit

Middle Aquitard Unit

Lower Aquifer Unit

Volcanic Unit

Faults

MW-8

Monitor Well

Screened interval

0 500 1000

HORIZONTAL SCALE IN FEET

0 50 100

VERTICAL SCALE IN FEET

FIGURE: 5	SOUTH PASS RESOURCES, Inc.				GEOLOGIC CROSS-SECTION B – B' Molycorp, Inc. Questa, New Mexico
	PROJECT No.: 001-02	DATE: 9-15-93	AUTHOR:	DRAWN BY: M.O'M.	

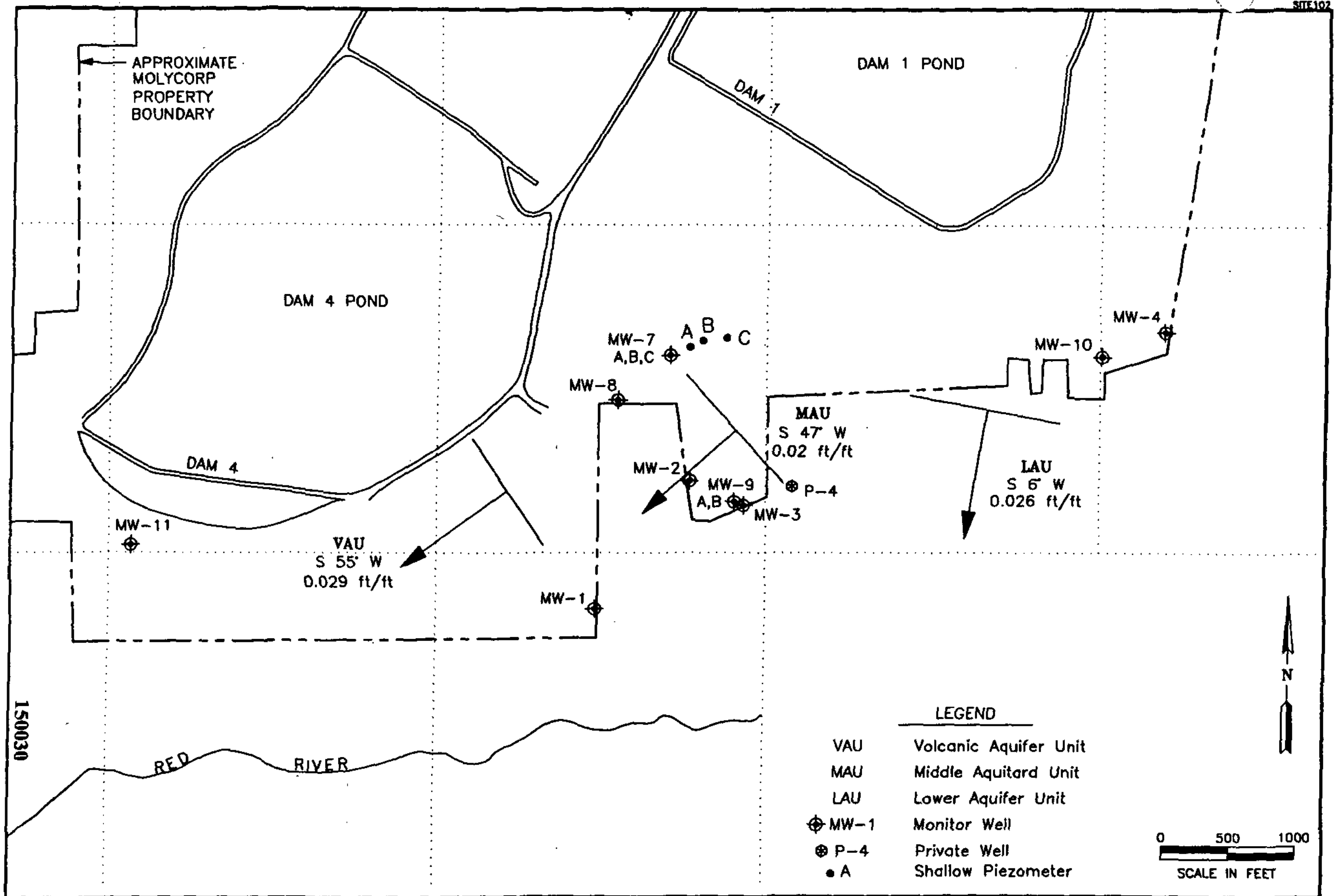
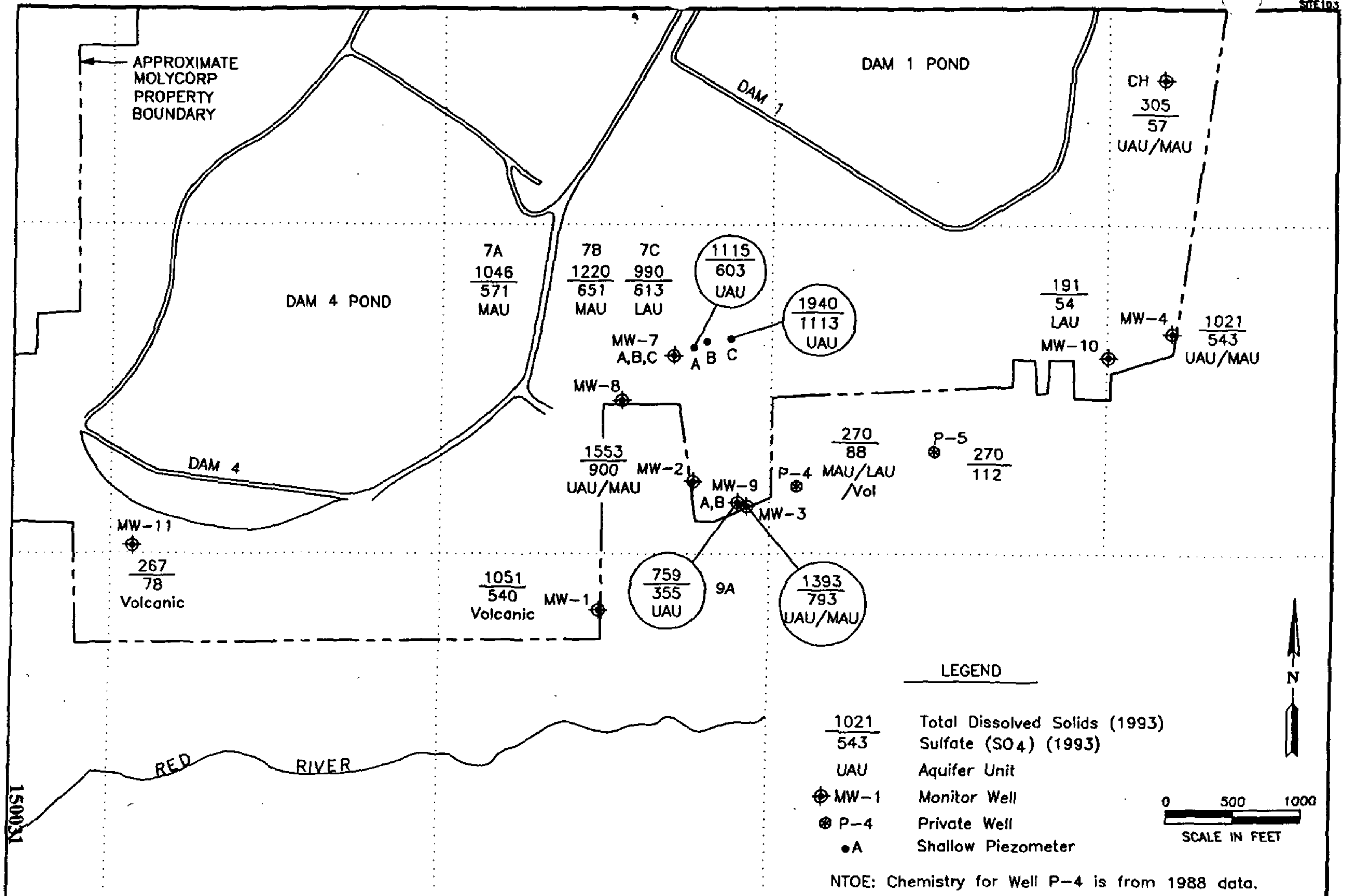


FIGURE: 6	SOUTH PASS RESOURCES, Inc.				GROUND-WATER FLOW DIRECTIONS & GRADIENTS Molycorp, Inc. Questa, New Mexico
	PROJECT No.: 001-02	DATE: 9-15-93	AUTHOR:	DRAWN BY: M.O'M.	

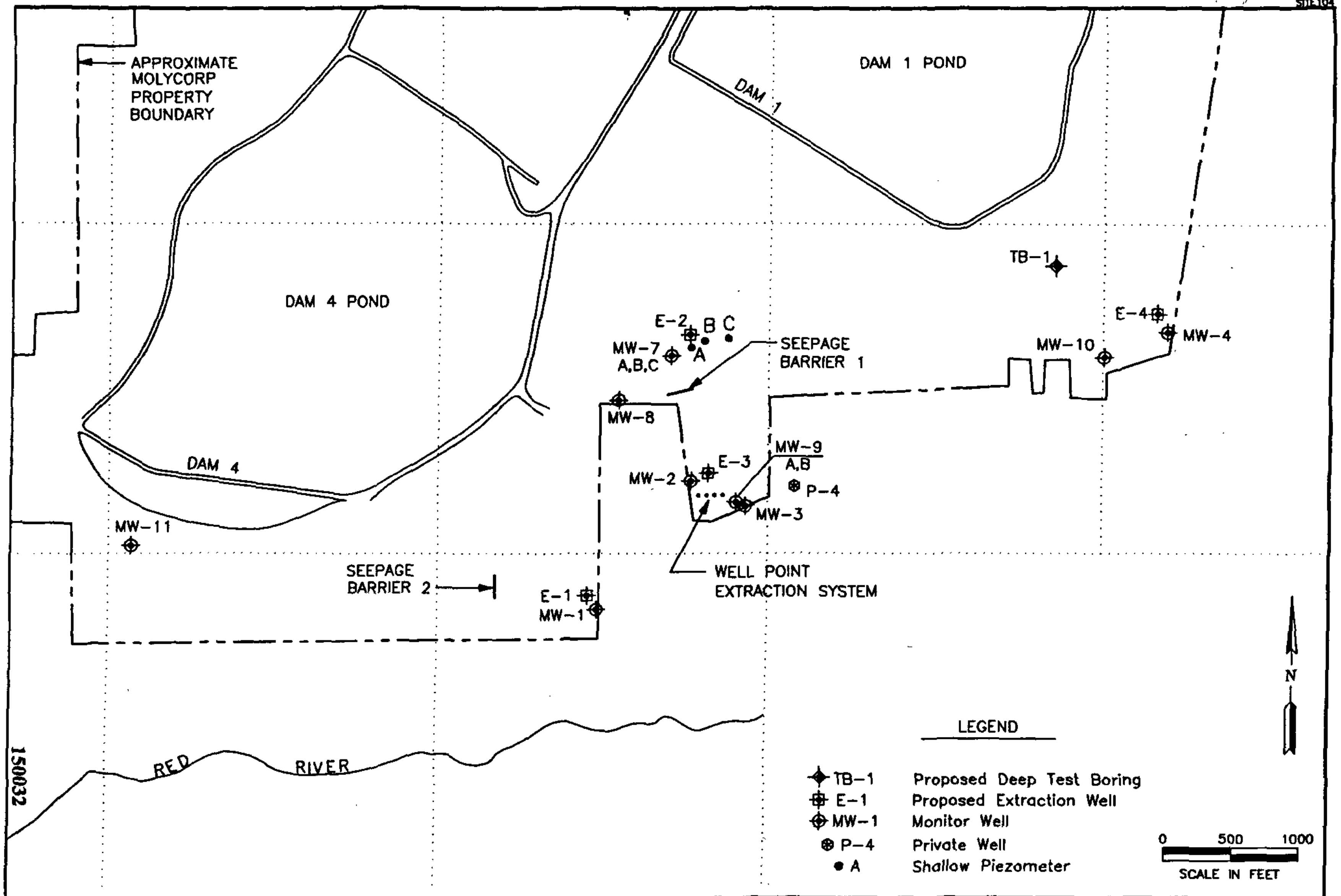


NTOE: Chemistry for Well P-4 is from 1988 data.

FIGURE: 7	SOUTH PASS RESOURCES, Inc.			
	PROJECT No.: 001-02	DATE: 9-15-93	AUTHOR:	DRAWN BY: M.O'M.

MONITOR WELL GROUND-WATER CHEMISTRY
Molycorp, Inc.
Questa, New Mexico

150031



150032

FIGURE: 8	SOUTH PASS RESOURCES, Inc.				EXTRACTION SYSTEM – TAILINGS PONDS AREA Molycorp, Inc. Questa, New Mexico
	PROJECT No.: 001-02	DATE: 9-20-93	AUTHOR:	DRAWN BY: M.O'M.	

000317

APPENDIX A

BOREHOLE LOGS

Boring Log No. MW-7

PROJECT NUMBER: 001-02 **DATE:** 9-20-93 **LOGGED BY:** W. J. Opfel
DRILL RIG: Air Rotary Casing Hammer **HOLE DIA.:** 12" in. **SAMPLER:** Grab
INITIAL GW DEPTH: ft. **FINAL GW:** ft. **HOLE ELEV.:** 7320.10

DESCRIPTION	USCS CLASS	GRAPHIC LOG	DEPTH	SAMPLE	BLOWS/FT.	REMARKS
TAN SILTY SANDY GRAVEL	GP		0			Final groundwater depths: 7A = 56.5' 7B = 82.3' 7C = 74.3'
TAN SILTY GRAVELLY SAND with tan silty sandy gravel (80%), 1 to 2 inches. No observable moisture.	SP		5	☒ (10)		
SILTY SANDY GRAVEL & SILTY GRAVELLY SAND layers alternate, with possible clay layers. Gravels appear to be fine-grained volcanics with a trace of plutonic sand from 25' to 26'; sand is brown, clayey and coarse-grained. Well-rounded brown to tan clay balls appear to be silty gravelly clay.	GM		15	☒ (20)		
SILTY GRAVELLY SAND & SILTY CLAY moist, with trace gravel.	GM / CL					
REDDISH BROWN SILTY SANDY CLAY	CL					
BROWN CLAYEY SANDY GRAVEL moist, poorly sorted angular (volcanics), with interbedded clay.	GC		30	☒ (30)		
BROWN SANDY GRAVEL & WHITE QUARTZ no clay, volcanic fragments.	GP		35			
			40			

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Environmental Consultants
Phoenix, Arizona

TAILINGS PONDS AREA
MOLYCORP, Inc.
Questa, New Mexico 150034

Figure No. **A1**

Boring Log No. MW-7

PROJECT NUMBER: 001-02 | **DATE:** 9-20-93 | **LOGGED BY:** W. J. Opfel
DRILL RIG: Air Rotary Casing Hammer | **HOLE DIA.:** 12" in. | **SAMPLER:** Grab
INITIAL GW DEPTH: ft. | **FINAL GW:** ft. | **HOLE ELEV.:** 7320.10

DESCRIPTION	USCS CLASS	GRAPHIC LOG	DEPTH	SAMPLE	BLOWS/FT.	REMARKS
	GP		40	☒		
			45			Losing water to formation above 55 feet
			50	☒		
gravelly/clayey mudballs at surface			55			
BROWN GRAVELLY CLAY fine-grained silicates (volcanic) up to 1 1/2", clay is silty.	CL					
BROWN CLAYEY GRAVEL light to dark fine-grained volcanics, small to large, up to 1 1/2".	GC		60	☒		
REDDISH BROWN GRAVELLY CLAY fine-grained, 1/4" to 1/2".	CL		65			
			70	☒		
			75			
coarse gravel at 77' to 78'			80			

Boring Log No. MW-7

PROJECT NUMBER: 001-02 **DATE:** 9-20-93 **LOGGED BY:** W. J. Opfel
DRILL RIG: Air Rotary Casing Hammer **HOLE DIA.:** 12" in. **SAMPLER:** Grab
INITIAL GW DEPTH: ft. **FINAL GW:** ft. **HOLE ELEV.:** 7320.10

DESCRIPTION	USCS CLASS	GRAPHIC LOG	DEPTH	SAMPLE	BLOWS/FT.	REMARKS
	CL		80	☒		
SANDY GRAVEL coarse-grained, mixed volcanics (80%) and plutonic (20%).	GM		85			Yielding water at 20 gpm
REDDISH BROWN GRAVELLY CLAY interbedded coarse sandy gravel. coarse gravel yielding water	CL GM		90 95 100 105	☒ ☒		Yielding water at 3 gpm at 107-108'
RED-BROWN GRAVELLY CLAY some green clay lenses, reddish brown clay is dense, dry and hard. coarse gravel with large 2" chips of clay, with red and green volcanic pieces 115' to 116'	CL		110 115 120	☒		

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Phoenix, Arizona

TAILINGS PONDS AREA
MOLYCORP, Inc.
Questa, New Mexico 150036

Figure No.
A1b

Boring Log No. MW-7

PROJECT NUMBER: 001-02 **DATE:** 9-20-93 **LOGGED BY:** W. J. Opfel
DRILL RIG: Air Rotary Casing Hammer **HOLE DIA.:** 12" in. **SAMPLER:** Grab
INITIAL GW DEPTH: ft. **FINAL GW:** ft. **HOLE ELEV.:** 7320.10

DESCRIPTION	USCS CLASS	GRAPHIC LOG	DEPTH	SAMPLE	BLOWS/FT.	REMARKS
gravel is red, green brown and black, volcanic fragments, clay is dense and dry	CL		120	⊠		
CLAYEY GRAVEL gravel up to 70-80%.	GC		125			Yielding water 5 to 8 gpm
TAN COARSE SANDSTONE with volcanic and granitic fragments, sandstone chips from 1/4" to 2", 35% quartz, 35% sandstone, 30% volcanics.	SS		130	⊠		
SANDY GRAVEL/GRAVELLY SANDS no indication of cementation; 35% granitic, 35% sandstone, 30% red and black volcanic fragments - 132' to 133'. 30% sandstone, 30% red and black volcanics - 133' to 138'. Volcanic gravel below 138'.	GP		135, 140, 145	⊠ (140)		
Boring terminated at 146.0 feet. See Monitor Well Completion Detail.			150, 155, 160			

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TAILINGS PONDS AREA
MOLYCORP, Inc.
Questa, New Mexico 150037

Figure No.
A1c

Boring Log No. MW-8

PROJECT NUMBER: 001-02 **DATE:** 9-20-93 **LOGGED BY:** J.C. Kepper & W.J. Opfel
DRILL RIG: Air Rotary Casing Hammer **HOLE DIA.:** 12" in. **SAMPLER:** Grab
INITIAL GW DEPTH: ft. **FINAL GW:** 105 ft. **HOLE ELEV.:** 7371.46

DESCRIPTION	USCS CLASS	GRAPHIC LOG	DEPTH	SAMPLE	BLOWS/FT.	REMARKS
BROWN GRAVEL well sorted rounded gravel, very coarse-grained sand, cobble fragments with volcanics, gneisses, and quartz fragments.	GW		0–10			
COBBLES tightly packed, mostly chips.	GP		10–14			
DARK BROWN SANDY GRAVEL damp, pebble and cobble chips with medium to very coarse-grained sand.	GP		14–20			
BROWN SANDY GRAVEL TO GRAVELLY SAND very moist, with clay stringers.	GW SP		20–24			
BROWN SANDY GRAVEL very coarse gravel (1 1/2" to 2 1/2") with medium- to very coarse- grained sand and clay stringers.	GM		24–30			
BROWN GRAVELLY CLAY & CLAYEY GRAVEL moist, interbedded clay and gravel with very fine- to fine-grained sand and silt; chips indicate very coarse gravel or cobbles in some layers.	CL GC		30–40			

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35, 40

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Environmental Consultants
Phoenix, Arizona

TAILINGS PONDS AREA
MOLYCORP, Inc.
Questa, New Mexico 150038

Figure No. **A2**

Boring Log No. MW-8

PROJECT NUMBER: 001-02 | **DATE:** 9-20-93 | **LOGGED BY:** J.C. Kepper & W.J. Opfel
DRILL RIG: Air Rotary Casing Hammer | **HOLE DIA.:** 12" in. | **SAMPLER:** Grab
INITIAL GW DEPTH: ft. | **FINAL GW:** 105 ft. | **HOLE ELEV.:** 7371.46

DESCRIPTION	USCS CLASS	GRAPHIC LOG	DEPTH	SAMPLE	BLOWS/FT.	REMARKS
SANDY CLAY moist, with layers of gravelly clay, very fine- to medium-grained sand , 20%-30% gravel up to 1 1/2".	CL		40			
			45			
PALE TO RED-BROWN-SANDY CLAY with stringers of clayey gravel and pebbles up to 1 1/2", 20%-30% sand in clay and silt.	CL		50			
			55			
BROWN SANDY GRAVEL coarse, 1 to 1 1/2" rounded to subrounded chips or larger clasts, sand is medium- to very coarse-grained, subrounded, some stringers of gravelly sand, gravel 60%, sand 40%.	GW		60			
			65			
BROWN GRAVELLY SANDY CLAY layers of sandy clayey gravel.	CL		70			
			75			
			80			

Boring Log No. MW-8

PROJECT NUMBER: 001-02
DRILL RIG: Air Rotary Casing Hammer
INITIAL GW DEPTH: ft.

DATE: 9-20-93
HOLE DIA.: 12" in.
FINAL GW: 105 ft.

LOGGED BY: J.C. Kepper & W.J. Opfel
SAMPLER: Grab
HOLE ELEV.: 7371.46

DESCRIPTION	USCS CLASS	GRAPHIC LOG	DEPTH	SAMPLE	BLOWS/FT.	REMARKS
SANDY CLAY	SC		80			
BROWN SANDY GRAVEL very fine gravel with interbedded gravelly sand layers. Sand is very fine- to coarse-grained.	GW		85, 90			
BROWN SANDY CLAYEY GRAVEL medium grained gravel, very fine- to medium-grained sand, 20% clay- silt matrix.	GC		95			
BROWN GRAVELLY SANDY CLAY pale red-brown clay from 104' to 106'.	CL		100, 105			
BROWN SANDY GRAVEL very coarse-grained sand and <3/4" gravel.	GW					
BROWN CLAYEY GRAVEL very fine gravel (subrounded).	GC					
PALE RED-BROWN SILTY SANDY CLAY 75 % very fine- to fine-grained sand, with less than 10% gravel.	CL		110, 115, 120			

SOUTH PASS RESOURCES, Inc.
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TAILINGS PONDS AREA
MOLYCORP, Inc.
Questa, New Mexico 150040

Figure No. **A2b**

Boring Log No. MW-8

PROJECT NUMBER: 001-02 **DATE:** 9-20-93 **LOGGED BY:** J.C. Kepper & W.J. Opfel
DRILL RIG: Air Rotary Casing Hammer **HOLE DIA.:** 12" in. **SAMPLER:** Grab
INITIAL GW DEPTH: ft. **FINAL GW:** 105 ft. **HOLE ELEV.:** 7371.46

DESCRIPTION	USCS CLASS	GRAPHIC LOG	DEPTH	SAMPLE	BLOWS/FT.	REMARKS
with thin gravel layers	CL		120			
BROWN SANDY GRAVEL 60%-70% rounded to subrounded gravel, some chips 1 1/2". Sand is medium- to very coarse-grained.	GP		125			
BROWN SANDY GRAVEL TO GRAVELLY SAND gravel up to 2", fine- to very coarse-grained sand.	GP SW		130			
PALE BROWN CLAY with silt, sand and less than 10% gravel.	CL		135			
BROWN SANDY GRAVEL	GW		140			
PALE RED-BROWN SANDY SILTY CLAY interbedded layers of clayey gravel and gravelly clay, sand is very fine- to fine-grained.	CL		145 150			
BASALT chips of vesicular and nonvesicular basalt, 155' to 165'			155 160			

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TAILINGS PONDS AREA
MOLYCORP, Inc.
Questa, New Mexico 150041

Figure No.
A2c

Boring Log No. MW-8

PROJECT NUMBER: 001-02 | **DATE:** 9-20-93 | **LOGGED BY:** J.C. Kepper & W.J. Opfel
DRILL RIG: Air Rotary Casing Hammer | **HOLE DIA.:** 12" in. | **SAMPLER:** Grab
INITIAL GW DEPTH: ft. | **FINAL GW:** 105 ft. | **HOLE ELEV.:** 7371.46

DESCRIPTION	USCS CLASS	GRAPHIC LOG	DEPTH	SAMPLE	BLOWS/FT.	REMARKS
			160			
brown clay chips, vesicular basalt, red and white quartz chips 165' to 175'			165			
BASALT WITH WHITE FELDSPAR PHENOCRYSTS white quartz chips.			170			
			175			
			180			
VOLCANIC CONGLOMERATE with minor fragments of quartz and pegmatitic *material.*			185			
			190			
			195			
			200			

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TAILINGS PONDS AREA
MOLYCORP, Inc.
Questa, New Mexico 150042

Figure No. **A2d**

Boring Log No. MW-8

PROJECT NUMBER: 001-02	DATE: 9-20-93	LOGGED BY: J.C. Kepper & W.J. Opfel
DRILL RIG: Air Rotary Casing Hammer	HOLE DIA.: 12" in.	SAMPLER: Grab
INITIAL GW DEPTH: ft.	FINAL GW: 105 ft.	HOLE ELEV.: 7371.46

DESCRIPTION	USCS CLASS	GRAPHIC LOG	DEPTH	SAMPLE	BLOWS/FT.	REMARKS
			200			
BLACK BASALT						
			205			
			210			
			215			
			220			
Boring terminated at 225 feet. See Monitor Well Completion Detail.			225			
			230			
			235			
			240			

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TAILINGS PONDS AREA
MOLYCORP, Inc.
Questa, New Mexico 150043

Figure No. A2e

Boring Log No. MW-9

PROJECT NUMBER: 001-02 **DATE:** 9-20-93 **LOGGED BY:** W. J. Opfel
DRILL RIG: Air Rotary Casing Hammer **HOLE DIA.:** 12" in. **SAMPLER:** Grab
INITIAL GW DEPTH: ft. **FINAL GW:** ft. **HOLE ELEV.:** 7326.00

DESCRIPTION	USCS CLASS	GRAPHIC LOG	DEPTH	SAMPLE	BLOWS/FT.	REMARKS
TAN SILTY SANDY GRAVEL	GM		0			
TAN SILTY SANDY CLAY	CL		5			
			10	⊠		
GRAVEL	GP					
TAN SILTY SANDY CLAY	CL					
TAN SANDY GRAVEL/GRAVELLY SAND moist, 80% volcanic gravels, 20% granitic gravels.	GP SP		15			
			20	⊠		
CLAYEY SANDY GRAVEL moist, clay content increase with depth.	GC		25			
			30	⊠		
BROWN CLAYEY GRAVEL/GRAVELLY CLAY moist.	GC CL		35			
			40			

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TAILINGS PONDS AREA
MOLYCORP, Inc.
Questa, New Mexico 150044

Figure No. **A3**

Boring Log No. MW-9

PROJECT NUMBER: 001-02 **DATE:** 9-20-93 **LOGGED BY:** W. J. Opfel
DRILL RIG: Air Rotary Casing Hammer **HOLE DIA.:** 12" in. **SAMPLER:** Grab
INITIAL GW DEPTH: ft. **FINAL GW:** ft. **HOLE ELEV.:** 7326.00

DESCRIPTION	USCS CLASS	GRAPHIC LOG	DEPTH	SAMPLE	BLOWS/FT.	REMARKS
	GC/CL		40	☒		
BROWN GRAVELLY CLAY moist.	CL		45			
BROWN CLAY moist, thin gravelly clay layers.	CL		50	☒		
BROWN CLAYEY GRAVEL moist. coarse sand and trace of gravel/gravelly clay, 62' to 65 feet	GC		55 60	☒		
BROWN GRAVELLY CLAY moist, thin layers of clayey gravel.	CL/GC		65 70	☒		
BROWN CLAYEY GRAVEL moist.	GC		75			
BROWN GRAVELLY CLAY moist.	CL		80			

Boring Log No. MW-9

PROJECT NUMBER: 001-02 **DATE:** 9-20-93 **LOGGED BY:** W. J. Opfel
DRILL RIG: Air Rotary Casing Hammer **HOLE DIA.:** 12" in. **SAMPLER:** Grab
INITIAL GW DEPTH: ft. **FINAL GW:** ft. **HOLE ELEV.:** 7326.00

DESCRIPTION	USCS CLASS	GRAPHIC LOG	DEPTH	SAMPLE	BLOWS/FT.	REMARKS
	CL		80	⊠		
BROWN CLAY moist, with trace gravel.	CL					
BROWN GRAVELLY CLAY	CL		85			
			90	⊠		
GRAVEL with trace clay.	GW		95			
			100	⊠		Losing return water at 10 gpm ~ 103' to 14'
CLAYEY GRAVEL/GRAVELLY CLAY gravel contains volcanic and granitic fragments.	GC CL		105			
			110	⊠		
BROWN CLAYEY GRAVEL with trace clay.	GC GW		115			making water, 1 to 2 gpm - 115' to 125'
			120			

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TAILINGS PONDS AREA
MOLYCORP, Inc.
Questa, New Mexico 150046

Figure No.
A3b

Boring Log No. MW-9

PROJECT NUMBER: 001-02 | **DATE:** 9-20-93 | **LOGGED BY:** W. J. Opfel
DRILL RIG: Air Rotary Casing Hammer | **HOLE DIA.:** 12" in. | **SAMPLER:** Grab
INITIAL GW DEPTH: ft. | **FINAL GW:** ft. | **HOLE ELEV.:** 7326.00

DESCRIPTION	USCS CLASS	GRAPHIC LOG	DEPTH	SAMPLE	BLOWS/FT.	REMARKS
	GC GW		120	⊠		
BROWN GRAVELLY CLAY	CL					
			125			
			130	⊠		
BROWN CLAYEY GRAVEL volcanic and white granitic fragments.	GC		135			
			140	⊠		
			145			
Boring terminated at 147 feet. See Well Completion Detail.						
			150			
			155			
			160			

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TAILINGS PONDS AREA
MOLYCORP, Inc.
Questa, New Mexico 150047

Figure No. **A3c**

Boring Log No. MW-10

PROJECT NUMBER: 001-02 **DATE:** 9-20-93 **LOGGED BY:** K. Zappetello
DRILL RIG: Air Rotary Casing Hammer **HOLE DIA.:** 12" in. **SAMPLER:** Grab
INITIAL GW DEPTH: ft. **FINAL GW:** 39 ft. **HOLE ELEV.:** 7353.20

DESCRIPTION	USCS CLASS	GRAPHIC LOG	DEPTH	SAMPLE	BLOWS/FT.	REMARKS
BROWN TO TAN SANDY SILTY CLAYEY GRAVEL sand is subrounded to angular, consists of quartz weathered basalt and granitic fragments.	GM		0 – 5			
BROWN TO TAN GRAVELLY SAND with silt and clay, gravels are well rounded.	SP SC		10	☒		
BROWN TO TAN GRAVELLY SANDY CLAY larger clasts of granitic fragments. gravels are rounded to angular	CL		15 – 20	☒		
BROWN TO TAN SANDY SILTY CLAYEY GRAVELS gravels are rounded to angular and consist of basalt and granitic fragments.	GC		25 – 30	☒		
SANDY CLAY moist, with well sorted subrounded gravels.	CL		35 – 40			

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TAILINGS PONDS AREA
MOLYCORP, Inc.
Questa, New Mexico 150048

Figure No. **A4**

Boring Log No. MW-10

PROJECT NUMBER: 001-02	**DATE:** 9-20-93	**LOGGED BY:** K. Zappetello
DRILL RIG: Air Rotary Casing Hammer	**HOLE DIA.:** 12" in.	**SAMPLER:** Grab
INITIAL GW DEPTH: ft.	**FINAL GW:** 39 ft.	**HOLE ELEV.:** 7353.20

DESCRIPTION	USCS CLASS	GRAPHIC LOG	DEPTH	SAMPLE	BLOWS/FT.	REMARKS
	CL		40	⊠		
BROWN SANDY GRAVELS with minor clay, gravels are rounded to angular.	GC		45 50	⊠		
BROWN GRAVELLY SANDY CLAY alternating gravels and clay, gravels are 1" to 2" diameter; clay balls are present.	CL		55 60 65	⊠		
BROWN TO TAN CLAYEY SILTY SANDY GRAVEL gravels are rounded to angular.	GC		70	⊠		
BROWN GRAVELLY SANDY CLAY alternating gravel and clays, gravels are well rounded 1/4" to 1/2".	CL		75 80			

SOUTH PASS RESOURCES, Inc. Environmental Consultants Phoenix, Arizona	TAILINGS PONDS AREA MOLYCORP, Inc. Questa, New Mexico 150049	Figure No. **A4a**

Boring Log No. MW-10

PROJECT NUMBER: 001-02 **DATE:** 9-20-93 **LOGGED BY:** K. Zappetello
DRILL RIG: Air Rotary Casing Hammer **HOLE DIA.:** 12" in. **SAMPLER:** Grab
INITIAL GW DEPTH: ft. **FINAL GW:** 38 ft. **HOLE ELEV.:** 7353.20

DESCRIPTION	USCS CLASS	GRAPHIC LOG	DEPTH	SAMPLE	BLOWS/FT.	REMARKS
	CL		80	☒		
			85			
BROWN TO TAN CLAYEY GRAVEL	GC					
BROWN TO TAN GRAVEL rounded to subangular clasts.	GW		90	☒		
BROWN TO TAN GRAVELLY SANDY CLAY	CL		95			
BROWN SANDY GRAVEL gravels 1/2" to 1".	GP		100	☒		
BROWN SANDY CLAYEY GRAVEL/GRAVELLY SANDY CLAY	GC CL		105			
BROWN TO TAN GRAVEL subrounded to angular.	GP					
BROWN SANDY CLAYEY GRAVEL/GRAVELLY SANDY CLAY	GC CL		110	☒		
			115			
BROWN GRAVELLY SANDY CLAY gravels rounded, 1/2" to 1".	CL		120			

SOUTH PASS RESOURCES, Inc. Environmental Consultants Phoenix, Arizona	TAILINGS PONDS AREA MOLYCORP, Inc. Questa, New Mexico 150050	Figure No. A4b

Boring Log No. MW-10

PROJECT NUMBER: 001-02	DATE: 9-20-93	LOGGED BY: K. Zappetello
DRILL RIG: Air Rotary Casing Hammer	HOLE DIA.: 12" in.	SAMPLER: Grab
INITIAL GW DEPTH: ft.	FINAL GW: 39 ft.	HOLE ELEV.: 7353.20

DESCRIPTION	USCS CLASS	GRAPHIC LOG	DEPTH	SAMPLE	BLOWS/FT.	REMARKS
	CL		120	⊠		
			125			
BASALT						
Boring terminated at 129.0 feet. See Monitor Well Completion Detail.			130			
			135			
			140			
			145			
			150			
			155			
			160			

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TAILINGS PONDS AREA
MOLYCORP, Inc.
Questa, New Mexico 150051

Figure No.
A4c

Boring Log No. MW-11

PROJECT NUMBER: 001-02 **DATE:** 9-20-93 **LOGGED BY:** J.C. Kepper
DRILL RIG: Air Rotary Cassing Hammer **HOLE DIA.:** 12" in. **SAMPLER:** Grab
INITIAL GW DEPTH: ft. **FINAL GW:** 191 ft. **HOLE ELEV.:** 7347.12

DESCRIPTION	USCS CLASS	DEPTH	SAMPLE	BLOWS/FT.	REMARKS
BROWN CLAYEY SAND well sorted sand, coarse gravel, gray volcanic rock. Volcanic rock clasts show varying amounts of weathering.	SC	0–24			
BLACK BASALT andesitic sand, minor quartz grains, rounded very coarse-grained sand, poorly sorted.	SP	24–27			
OLIVINE/AUGITE BEARING BASALT chips up to 2".		27–43			
BROWN VOLCANIC CONGLOMERATE rounded 1 inch pebbles of basalt in quartz and volcanic sand matrix; fine- to coarse-grained sand.	GW	43–48			
BLACK TO GRAY OLIVINE AUGITE BASALT pale blue silica coating on fracture surfaces; chips 1/2" or less. Thin gray volcanic sandstone within the interval.		48–70			
BLACK TO GRAY OLIVINE AUGITE BASALT highly vesicular rock; chips 1" or less.		70–80			

Depth scale: 0, 10, 20, 30, 40, 50, 60, 70, 80

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Phoenix, Arizona

TAILINGS PONDS AREA
MOLYCORP, Inc.
Questa, New Mexico 150052

Figure No. **A5**

Boring Log No. MW-11

PROJECT NUMBER: 001-02	**DATE:** 9-20-93	**LOGGED BY:** J.C. Kepper
DRILL RIG: Air Rotary Cassing Hammer	**HOLE DIA.:** 12" in.	**SAMPLER:** Grab
INITIAL GW DEPTH: ft.	**FINAL GW:** 191 ft.	**HOLE ELEV.:** 7347.12

DESCRIPTION	USCS CLASS	GRAPHIC LOG	DEPTH	SAMPLE	BLOWS/FT.	REMARKS
			80			
MEDIUM GRAY VOLCANIC finely crystalline with pink to light brown vuggy bands, flow bands; chips 1 1/2" or less.			90			
			100			
MEDIUM GRAY OLIVINE AUGITE BASALT minor 2" chips of red volcanic breccia gray volcanic fine scoraceous texture; chips up to 2".			110			
			120			
MEDIUM TO DARK GRAY VOLCANIC BASALT trace olivine/augite, scoraceous to dense; chips 1" or less (1/4" common).			130			
			140			
some fine white feldspar crystals in basalt; red fracture coatings; chips 1" or less (1/4" common).			150			
			160			

Boring Log No. MW-11

PROJECT NUMBER: 001-02 **DATE:** 9-20-93 **LOGGED BY:** J.C. Kepper
DRILL RIG: Air Rotary Casing Hammer **HOLE DIA.:** 12" in. **SAMPLER:** Grab
INITIAL GW DEPTH: ft. **FINAL GW:** 191 ft. **HOLE ELEV.:** 7347.12

DESCRIPTION	USCS CLASS	GRAPHIC LOG	DEPTH	SAMPLE	BLOWS/FT.	REMARKS
chips 1" or less (1/2" common).			160			
MEDIUM GRAY-PINK TO BROWN VOLCANIC ROCK vuggy bands, flow bands, large 3/4" chip common.			170			
			180			
DARK GRAY TO BLACK BASALT trace augite/olivine; trace brown to pink vuggy bands; large 3/4" chips common.			190			
			200			
strong flow water at joint change at 212 feet chips up to 1"			210			
			220			
			230			
			240			

SOUTH PASS RESOURCES, Inc.
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Phoenix, Arizona

TAILINGS PONDS AREA
MOLYCORP, Inc.
Questa, New Mexico

150054

Figure No. **A5b**

Boring Log No. MW-11

PROJECT NUMBER: 001-02 | **DATE:** 9-20-93 | **LOGGED BY:** J.C. Kepper
DRILL RIG: Air Rotary Cassing Hammer | **HOLE DIA.:** 12" in. | **SAMPLER:** Grab
INITIAL GW DEPTH: ft. | **FINAL GW:** 191 ft. | **HOLE ELEV.:** 7347.12

DESCRIPTION	USCS CLASS	GRAPHIC LOG	DEPTH	SAMPLE	BLOWS/FT.	REMARKS
			240			
some chips look glossy; chips 1" to 1 1/2" common						
making 200 to 300 gpm, hole caving badly.			250			
Boring terminated at 256.0 feet. See Monitor Well Completion Detail.						
			260			
			270			
			280			
			290			
			300			
			310			
			320			

SOUTH PASS RESOURCES, Inc.
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Phoenix, Arizona

TAILINGS PONDS AREA
MOLYCORP, Inc.
Questa, New Mexico

150055

Figure No. **A5c**

APPENDIX B

RESULTS OF LABORATORY ANALYSES

OF AQUITARD SAMPLES

SHB AGRA INC.
ENGINEERING & ENVIRONMENTAL SERVICES

PROJECT: SOUTHPASS RESOURCES

LOCATION: MW-9 @ 55'-55.5'

PROJECT NO: LT93-3971
W O NO: 2
LAB NO: 9
DATE: 8/17/93

MECHANICAL SIEVE ANALYSIS (ASTM C136)

SIEVE SIZE	% PASSING
2 IN	100
1 1/2 IN	100
1 IN	100
3/4 IN	94
1/2 IN	75
3/8 IN	70
1/4 IN	68
#4	67
#8	67
#10	66
#16	66
#30	65
#40	64
#50	62
#100	58
#200	51.4

MOISTURE CONTENT = 2.5%

150057

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PROJECT	SOUTHPASS RESOURCES	JOB No	LT93-3971
SAMPLE	MW-9 @ 55'-55.5'	W. O. No	2
		LAB NO.	9
		DATE	8/9/93

HYDROMETER TEST REPORT (ASTM D-422)

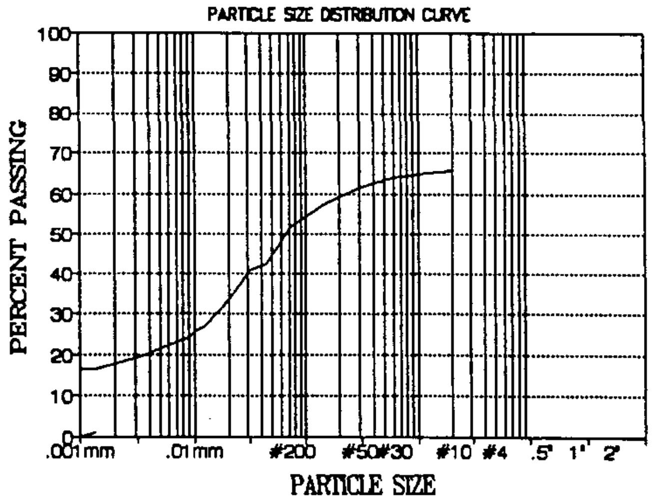
WEIGHT OF SAMPLE DISPERSED	48.70	SPECIFIC GRAVITY OF SOLIDS	2.541
PERCENT PASSING #10 SIEVE	66.00		

CALCULATED RESULTS

PARTICAL SIZE (DIA. mm)	0.0440	0.0314	0.0205	0.0122	0.0088	0.0063	0.0032	0.0014
PERCENT SAMPLE TESTED	63.8	61.7	51.3	40.8	36.4	34.2	29.5	25.2
PERCENT TOTAL SAMPLE	42.1	40.8	33.8	26.9	24.0	22.6	19.5	16.6

SIEVE ANALYSIS AFTER HYDROMETER ACCUMULATED % PASSING

#200	#100	#50	#40	#30	#16	#10
52	57	62	63	64	65	66



150058
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PROJECT:	SOUTHPASS RESOURCES	**JOB NO.**	LT93-3971
SOURCE:	MW-9 @ 55'-55.5'	**W.O. NO.**	2
		LAB NO.	9
		DATE	8/8/93

SPECIFIC GRAVITY OF SOIL (ASTM D854)

O.D. WT. OF SOIL	49.85
WT OF FLASK + H2O	363.38
WT FLASK+H20+SSD	393.61
SPECIFIC GRAVITY	2.541

150059
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PROJECT:	SOUTHPASS RESOURCES	JOB NO.	LT93-3971
SAMPLE:	MW-9 @ 55'-55.5'	W.O. NO.	2
		LAB NO.	9
		DATE	8/1/93

PERMEABILITY TEST (ASTM D2434-68) FIXED WALL

WET DENSITY	123.3	pcf
DRY DENSITY	104.0	pcf
VOLUME	271.840	cc
INITAL MOISTURE	9.2%	
MOISTURE @ SATURATION	18.5%	

HEAD inches	PSI	Q cc	TIME sec.	K cm/sec	K ft/yr
16.06	0	107	5880	3.44E-04	3.55E+02
13.00	0	21	2100	2.32E-04	2.40E+02
12.13	0	16	2520	1.55E-04	1.61E+02
11.13	0	26	4260	1.67E-04	1.73E+02

150060
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PROJECT:	SOUTHPASS RESOURCES	**JOB NO.**	LT93-3971
SAMPLE:	MW-9 @ 55.5'-56'	**W.O. NO.**	2
		LAB NO.	10
		DATE	8/1/93

PERMEABILITY TEST (ASTM D2434-68) FIXED WALL

WET DENSITY	125.5 pcf
DRY DENSITY	102.5 pcf
VOLUME	204.658 cc
INITAL MOISTURE	13.1%
MOISTURE @ SATURATION	22.4%

HEAD inches	PSI	Q cc	TIME sec.	K cm/sec	K ft/yr
9.65	0	22	5700	9.40E-05	9.73E+01
20.00	0	16	2400	7.70E-05	7.96E+01
19.06	0	24	3120	9.32E-05	9.64E+01
18.00	0	21	4140	6.61E-05	6.84E+01

150061
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SHB AGRA INC.
ENGINEERING & ENVIRONMENTAL SERVICES

PROJECT: SOUTHPASS RESOURCES

LOCATION: MW-9 @ 56'-56.5'

PROJECT NO: LT93-3971
W O NO: 2
LAB NO: 11
DATE: 8/17/93

MECHANICAL SIEVE ANALYSIS (ASTM C136)

SIEVE SIZE	% PASSING
2 IN	100
1 1/2 IN	100
1 IN	100
3/4 IN	100
1/2 IN	87
3/8 IN	79
1/4 IN	77
#4	76
#8	75
#10	75
#16	74
#30	73
#40	72
#50	70
#100	66
#200	58.2

MOISTURE CONTENT = 2.2%

150062

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ENGINEERING & ENVIRONMENTAL SERVICES

PROJECT	SOUTHPASS RESOURCES	JOB No	LT93-3971
SAMPLE	MW-9 @ 56'-56.5'	W. O. No	2
		LAB NO.	11
		DATE	8/9/93

HYDROMETER TEST REPORT (ASTM D-422)

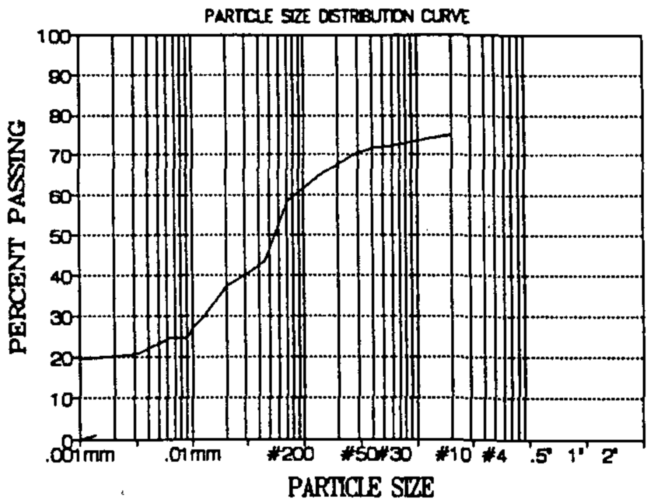
WEIGHT OF SAMPLE DISPERSED	50.27	SPECIFIC GRAVITY OF SOLIDS	2.531
PERCENT PASSING #10 SIEVE	75.00		

CALCULATED RESULTS

PARTICAL SIZE (DIA. mm)	0.0448	0.0319	0.0205	0.0123	0.0090	0.0063	0.0032	0.0014
PERCENT SAMPLE TESTED	57.9	54.0	49.9	39.6	33.2	33.2	27.6	26.5
PERCENT TOTAL SAMPLE	43.4	40.5	37.4	29.7	24.9	24.9	20.7	19.9

SIEVE ANALYSIS AFTER HYDROMETER ACCUMULATED % PASSING

#200	#100	#50	#40	#30	#16	#10
59	65	70	72	72	74	75



150063

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SHB AGRA, INC.
ENGINEERING & ENVIRONMENTAL SERVICES

PROJECT:	SOUTHPASS RESOURCES	**JOB NO.**	LT93-3971
SOURCE:	MW-9 @ 56'-56.5'	**W.O. NO.**	2
		LAB NO.	11
		DATE	8/8/93

SPECIFIC GRAVITY OF SOIL (ASTM D854)

O.D. WT. OF SOIL	52.09
WT OF FLASK + H2O	366.4
WT FLASK+H20+SSD	397.91
SPECIFIC GRAVITY	2.531

150064

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PROJECT:	SOUTHPASS RESOURCES	**JOB NO.**	LT93-3971
SAMPLE:	MW-9 @ 56'-56.5'	**W.O. NO.**	2
		LAB NO.	11
		DATE	8/1/93

PERMEABILITY TEST (ASTM D2434-68) FIXED WALL

WET DENSITY	115.9	pcf
DRY DENSITY	95.9	pcf
VOLUME	228.729	cc
INITAL MOISTURE	13.3%	
MOISTURE @ SATURATION	20.8%	

HEAD inches	PSI	Q cc	TIME sec.	K cm/sec	K ft/yr
10.50	0	63	40.02	3.76E-02	3.89E+04
7.50	0	63	55.98	3.76E-02	3.89E+04
11.00	0	42	25.02	3.82E-02	3.96E+04
7.00	0	42	60	2.51E-02	2.59E+04

150065

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PROJECT: SOUTHPASS RESOURCES

LOCATION: MW-9 @ 85'-85.5'

PROJECT NO: LT93-3971
W O NO: 2
LAB NO: 12
DATE: 8/17/93

MECHANICAL SIEVE ANALYSIS (ASTM C136)

SIEVE SIZE	% PASSING
2 IN	100
1 1/2 IN	100
1 IN	100
3/4 IN	100
1/2 IN	96
3/8 IN	90
1/4 IN	84
#4	83
#8	81
#10	81
#16	80
#30	78
#40	77
#50	75
#100	70
#200	63.5

MOISTURE CONTENT = 8.7%

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PROJECT	SOUTHPASS RESOURCES	JOB No	LT93-3971
SAMPLE	MW-9 @ 85'-85.5'	W. O. No	2
		LAB NO.	12
		DATE	8/9/93

HYDROMETER TEST REPORT (ASTM D-422)

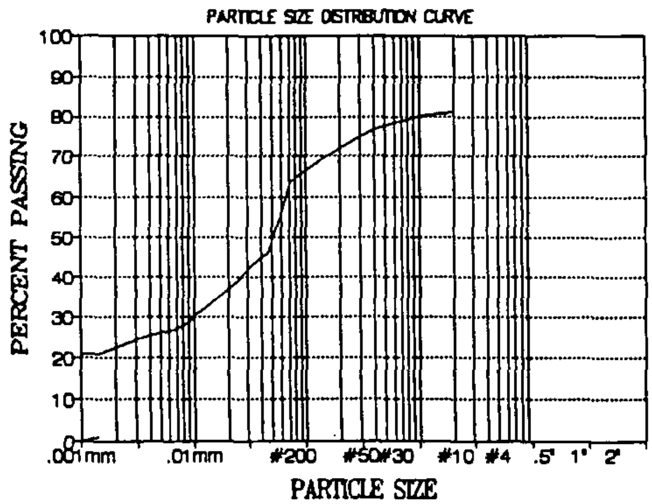
WEIGHT OF SAMPLE DISPERSED	47.77	SPECIFIC GRAVITY OF SOLIDS	2.498
PERCENT PASSING #10 SIEVE	81.00		

CALCULATED RESULTS

PARTICAL SIZE (DIA. mm)	0.0460	0.0329	0.0212	0.0126	0.0090	0.0065	0.0032	0.0014
PERCENT SAMPLE TESTED	57.0	52.7	46.2	39.6	35.3	33.0	30.4	25.9
'ERCENT TOTAL SAMPLE	46.2	42.7	37.4	32.1	28.6	26.7	24.6	21.0

SIEVE ANALYSIS AFTER HYDROMETER ACCUMULATED % PASSING

#200	#100	#50	#40	#30	#16	#10
64	70	75	77	78	80	81



150067

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000352

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PROJECT:	SOUTHPASS RESOURCES	JOB NO.	LT93-3971
SOURCE:	MW-9 @ 85'-85.5'	W.O. NO.	2
		LAB NO.	12
		DATE	8/8/93

SPECIFIC GRAVITY OF SOIL (ASTM D854)

O.D. WT. OF SOIL	40.11
WT OF FLASK + H2O	353
WT FLASK+H20+SSD	377.05
SPECIFIC GRAVITY	2.498

150068
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SHB AGRA INC.
ENGINEERING & ENVIRONMENTAL SERVICES

PROJECT:	SOUTHPASS RESOURCES	JOB NO.	LT93-3971
SAMPLE:	MW-9 @ 85'-85.5'	W.O. NO.	2
		LAB NO.	12
		DATE	8/1/93

PERMEABILITY TEST (ASTM D2434-68) FIXED WALL

WET DENSITY	123.4	pcf
DRY DENSITY	101.7	pcf
VOLUME	225.828	cc
INITAL MOISTURE	13.4%	
MOISTURE @ SATURATION	21.4%	

HEAD inches	PSI	Q cc	TIME sec.	K cm/sec	K ft/yr
15.00	0	42	255	2.75E-03	2.85E+03
13.50	0	21	181.8	2.14E-03	2.22E+03
12.50	0	21	172.2	2.44E-03	2.53E+03
11.31	0	29	331.02	1.93E-03	2.00E+03

150069

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ENGINEERING & ENVIRONMENTAL SERVICES

PROJECT:	SOUTHPASS RESOURCES	**JOB NO.**	LT93-3971
SAMPLE:	MW-9 @ 85.5'-86'	**W.O. NO.**	2
		LAB NO.	13
		DATE	8/1/93

PERMEABILITY TEST (ASTM D2434-68) FIXED WALL

WET DENSITY	133.0	pcf
DRY DENSITY	110.6	pcf
VOLUME	265.282	cc
INITAL MOISTURE	14.9%	
MOISTURE @ SATURATION	20.3%	

HEAD		Q	TIME	K	K
inches	PSI	cc	sec.	cm/sec	ft/yr
13.13	23	26	25560	5.03E-07	5.21E-01
18.22	28	33	28500	4.62E-07	4.78E-01
16.25	28	50	50700	3.96E-07	4.09E-01
19.50	28	21	13380	6.29E-07	6.51E-01

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APPENDIX C

RESULTS OF LABORATORY

ANALYSES OF WATER SAMPLES

(AUGUST 17-18, 1993)

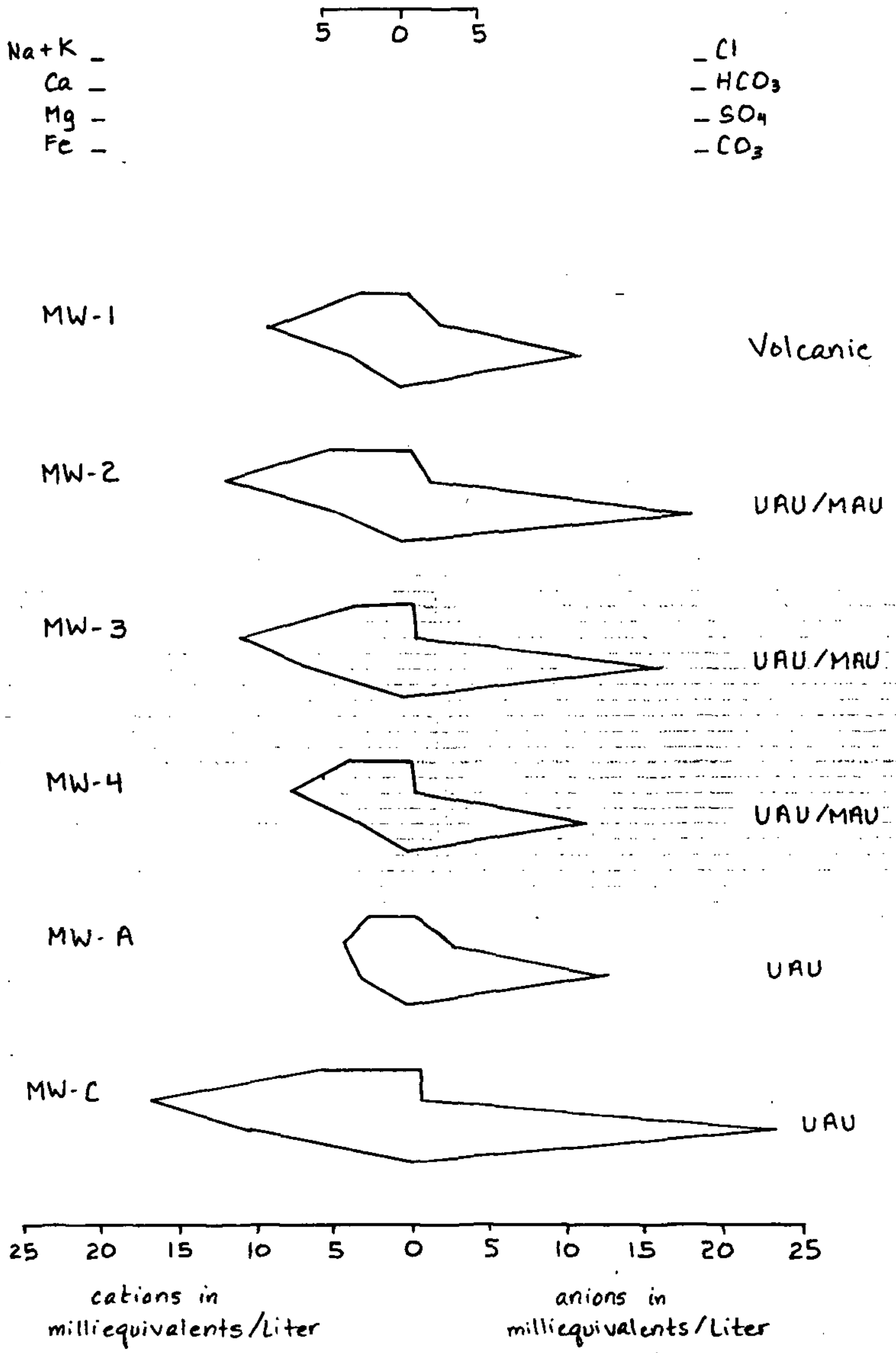
TABLE C-1
MONITOR WELL CHEMISTRY

Boring or Monitor Well #	MW-1	MW-2	MW-3	MW-4	MW-A	MW-C	MW-7A	MW-7B	MW-7C	MW-9A	MW-10	MW-11	CH
pH	7.9	7.7	7.4	7.3	7.4	7.2	7.1	8.9	10.6	7.6	8.1	8.1	7.7
TDS	1051	1553	1393	1021	1115	1940	1046	1220	990	759	191	267	305
Sulfate	540	900	793	543	603	1113	571	651	613	355	54	78	57
Sodium	56	102	72	86	58	117	41	80	81	47	36	32	98
Potassium	3.5	4.7	3.5	1.4	2.4	6.5	1.9	<1.0	157	1.3	1.8	3.1	117
Calcium	169	231	219	155	189	339	185	163	119	130	18	34	30
Magnesium	39	52	48	38	38	61	36	3.1	<1	26	3.3	11	6
Arsenic	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005	<.005
Aluminum	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Cadmium	<.0005	<.0005	<.0005	<.0005	<.0005	<.0005	<.0005	<.0005	<.0005	<.0005	<.0005	<.0005	<.0005
Chromium	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.034	<.001	0.002	0.001	0.003
Lead	<.002	<.002	<.002	<.002	<.002	<.002	<.002	<.002	0.006	<.002	<.002	<.002	<.002
Molybdenum	0.08	1.8	<.005	0.21	0.50	2.8	0.04	<.005	<.005	0.02	0.02	0.09	<.005
Iron	0.06	0.06	0.03	0.05	0.20	0.05	<.02	<.02	0.03	<.02	0.03	<.02	<.02
Manganese	0.03	0.58	<.01	<.01	0.05	2.6	<.01	<.01	<.01	1.2	<.01	0.01	<.01
Copper	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Zinc	0.014	0.00	0.00	0.00	0.00	0.00	0.03	0.20	0.008	0.12	0.038	0.014	0.007
Carbonate Alkalinity	<1	<1	<1	<1	<1	<1	<1	10	24	<1	<1	<1	<1
Bicarbonate Alkalinity	148	116	17	18	156	18	134	<1	<1	169	66	81	187
Hydroxide Alkalinity	<1	<1	<1	<1	<1	<1	<1	3	300	<1	<1	<1	<1
Fluoride	0.34	0.92	0.45	0.71	0.37	2.8	0.25	0.19	0.78	0.16	0.65	0.66	1.20

150072

001-02.XLS

South Pass Resources PROJECT RECORD	Client: Molycorp Inc., Questa	Job No. 001-02
	Project: Tailings Pond	Date: 9-20-93
	Subject: Stiff Diagrams	Page 1 of 2



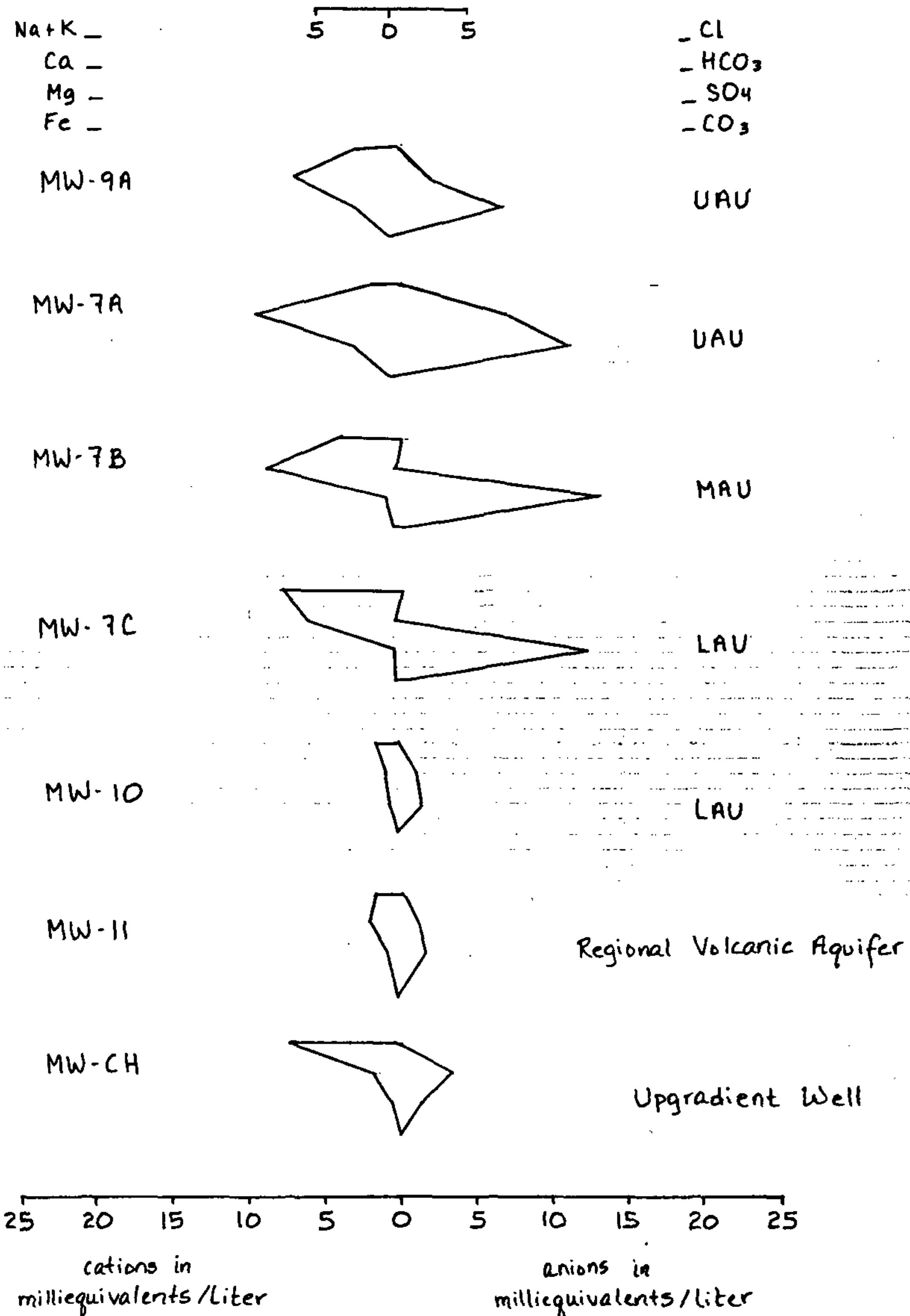
150073

Record By: JCK	Date:	Cked By:	Appr. By:
Revised By:	Date:	Cked By:	Appr. By:

C2

000358

South Pass Resources PROJECT RECORD	Client: Molycorp Inc, Questa	Job No. 001-02
	Project: Tailings Pond	Date: 9-20-93
	Subject: Stiff Diagrams	Page 2 of 2



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Revised By:	Date:	Cked By:	Appr. By:

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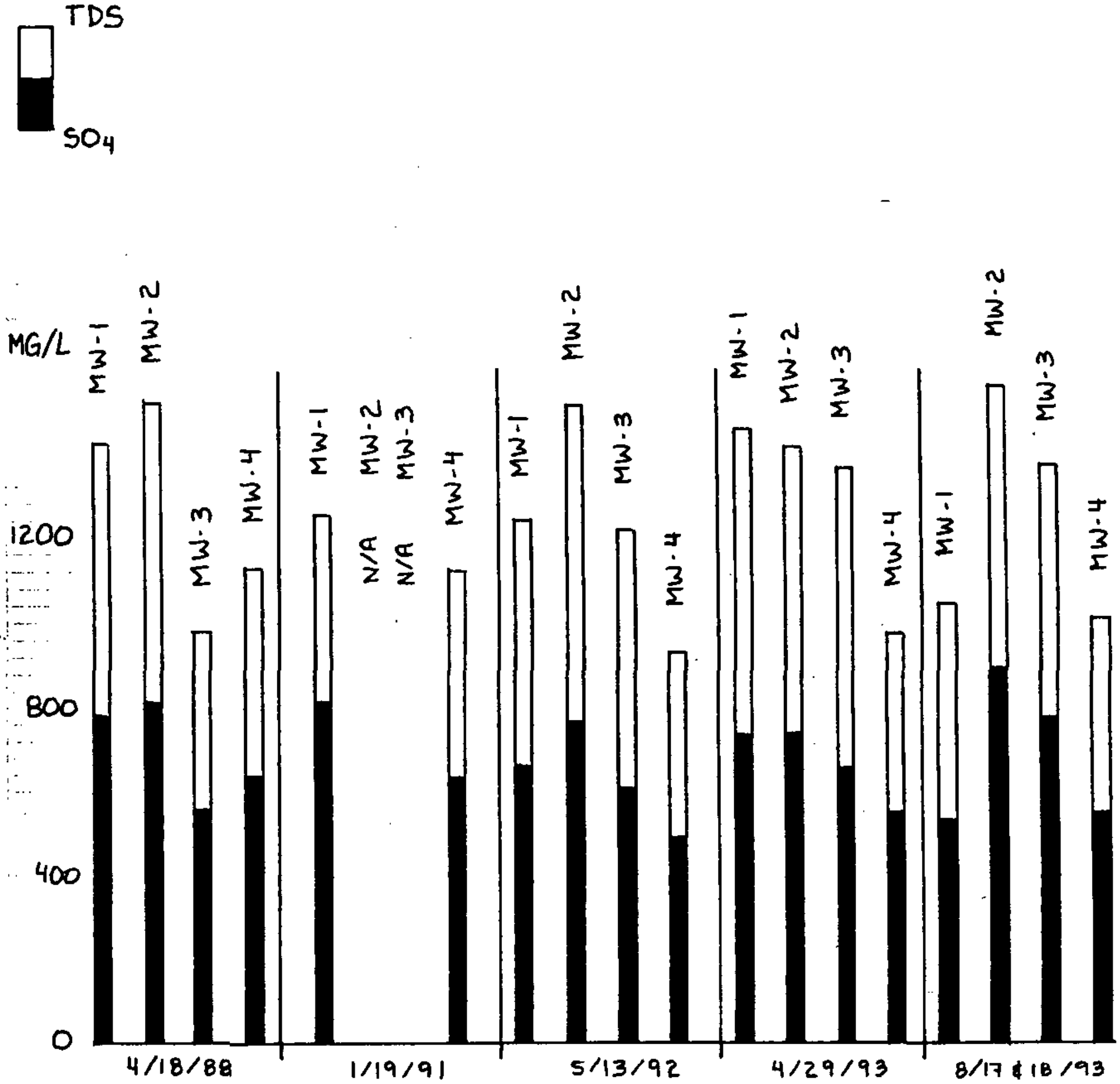

150075

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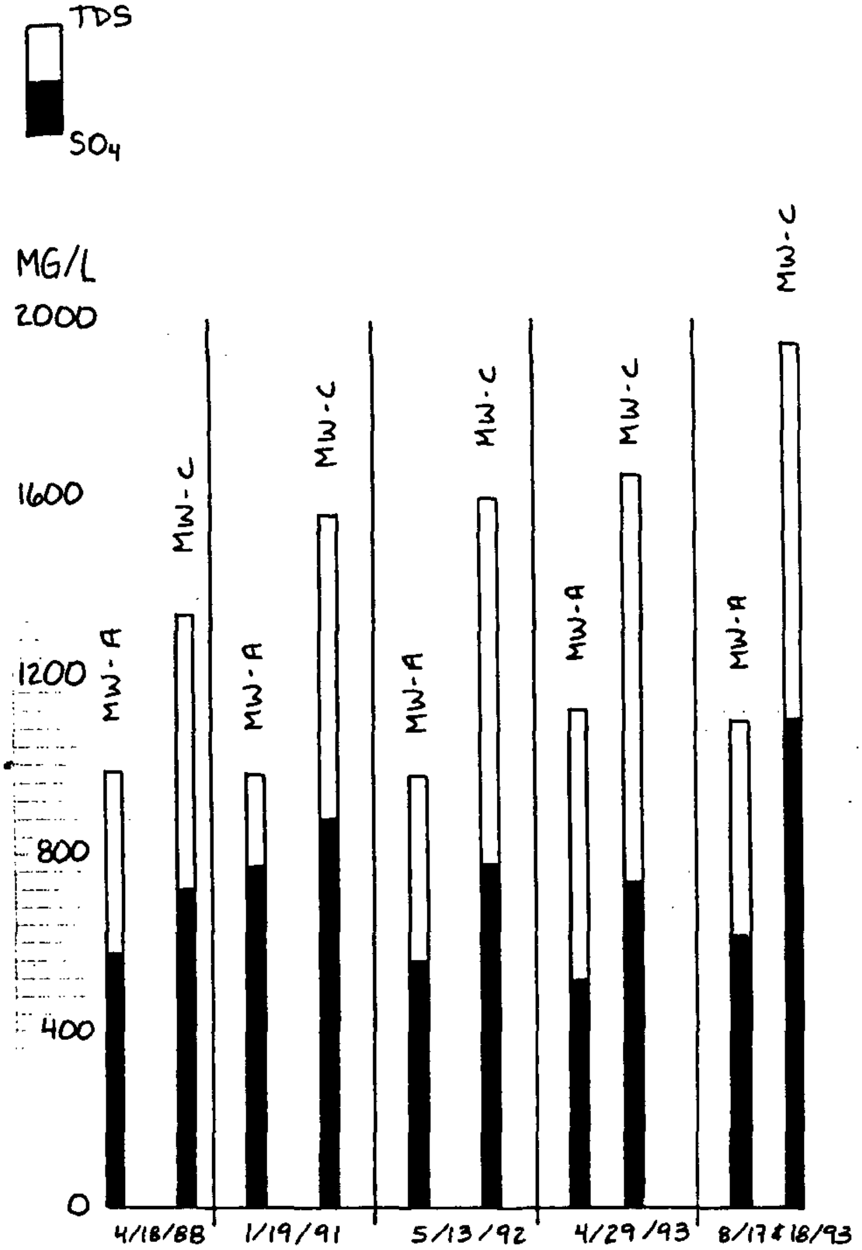
Revised By:	Date:	Cked By:	Appr. By:

C3

000360

South Pass Resources PROJECT RECORD	Client: Molycorp Inc., Questa	Job No. 001-02
	Project: Tailings Pond	Date: 9-20-93
	Subject: Histograms - MW Chemistry	Page 2 of 2



150076

Record By: JCK	Date:	Cked By:	Appr. By:
Revised By:	Date:	Cked By:	Appr. By:

000361

APPENDIX D

CONSTANT RATE AND

RECOVERY TEST RESULTS

APPENDIX D

CONSTANT RATE AND RECOVERY TEST RESULTS

A pump test was designed to stress the aquifers screened in the volcanic unit and in the Lower Alluvial Unit for an appropriate period of time to estimate transmissivity. The pump test was preceded by a step test to evaluate the maximum pumping rate for each well.

Monitor well MW-11, located south of Dam No. 4 in the bottom of a small canyon near Pope Lake, was used to test the volcanic unit. Monitor well MW-10, which is located just north of the county road near the southeastern corner of the Molycorp property, was used to test the Lower Aquifer Unit.

PUMP TEST PROCEDURES

Pumping Equipment

MW-11 was pumped using a 60-horsepower submersible pump capable of pumping 660 gpm. The flow rate was controlled by a gate valve and a flow meter located at the top of the discharge pipe. A diesel generator powered the pump. The intake for the pump was set at 235 feet.

MW-10 was pumped using a 4-inch submersible pump capable of pumping 15 gpm. The flow rate was controlled by a gate valve and a flow meter located at the top of the discharge pipe. A gas generator powered the pump. The intake for the pump was set at 117 feet.

Discharge and Water-Level Measurements

Discharge during the pump test was measured using a totalizing flow meter and a stopwatch. Water-level measurements were made with a transducer and a Hermit 1000C datalogger that were programmed to take measurements on a logarithmic time scale and that were installed at the same time as the pumps. Hand measurements with an electric sounder were not possible after the pump and transducers were installed because well diameters were not large enough to accommodate the additional probe.

Pump Test Procedures: MW-11

Static water levels were measured prior to the test using an electric sounder. After the transducer was installed at 221.15 feet below the top of the casing, static water levels were measured with the datalogger.

A step-drawdown test was performed at 11:27 on August 17, 1993 for 45 minutes. The purpose of the step test was to evaluate the drawdown response of the well at a pumping rate(s) below maximum rate. The pumping rate was set at approximately 530 gpm. Water-level measurements were recorded by a datalogger at the following intervals:

Elapsed Time:	Measurement Interval
0-1 minute	0.2 second
1-10 minutes	0.2 minute
10-100 minutes	2 minutes
100-1,000 minutes	20 minutes

After pumping was shut off, the datalogger was stepped so that recovery could be recorded at the same intervals as described above. Less than 1.0 foot of drawdown was recorded at 530 gpm, and the rate was increased to the maximum of 660 gpm for the constant rate test.

The pump test was not started until the aquifer had fully recovered. Due to the high flow velocity in the aquifer, over 99 percent of the recovery took place within the hour.

The pump test was performed at 16:07 and was conducted for 230 minutes. The pump rate was set at a maximum of 660 gpm. Water-level measurements were recorded at the same intervals described above. Recovery was quite rapid, again within an hour, though the datalogger was allowed to record recovery data until the following morning.

Pump Test Procedures: MW-10

Depth to static water level for this well was based on a measurement made immediately after well construction (91 feet bgs). The transducer was set at 117 feet below the top of the casing. A step test was run at 15 gpm, but after 10 minutes the well was pumped dry. The rate was then lowered to 5 gpm, but the water started becoming cloudy and the pump was shutdown. The information was not recorded correctly by the datalogger. The higher water level at the time of the pump test (39.0 feet) was likely the result of post-construction development.

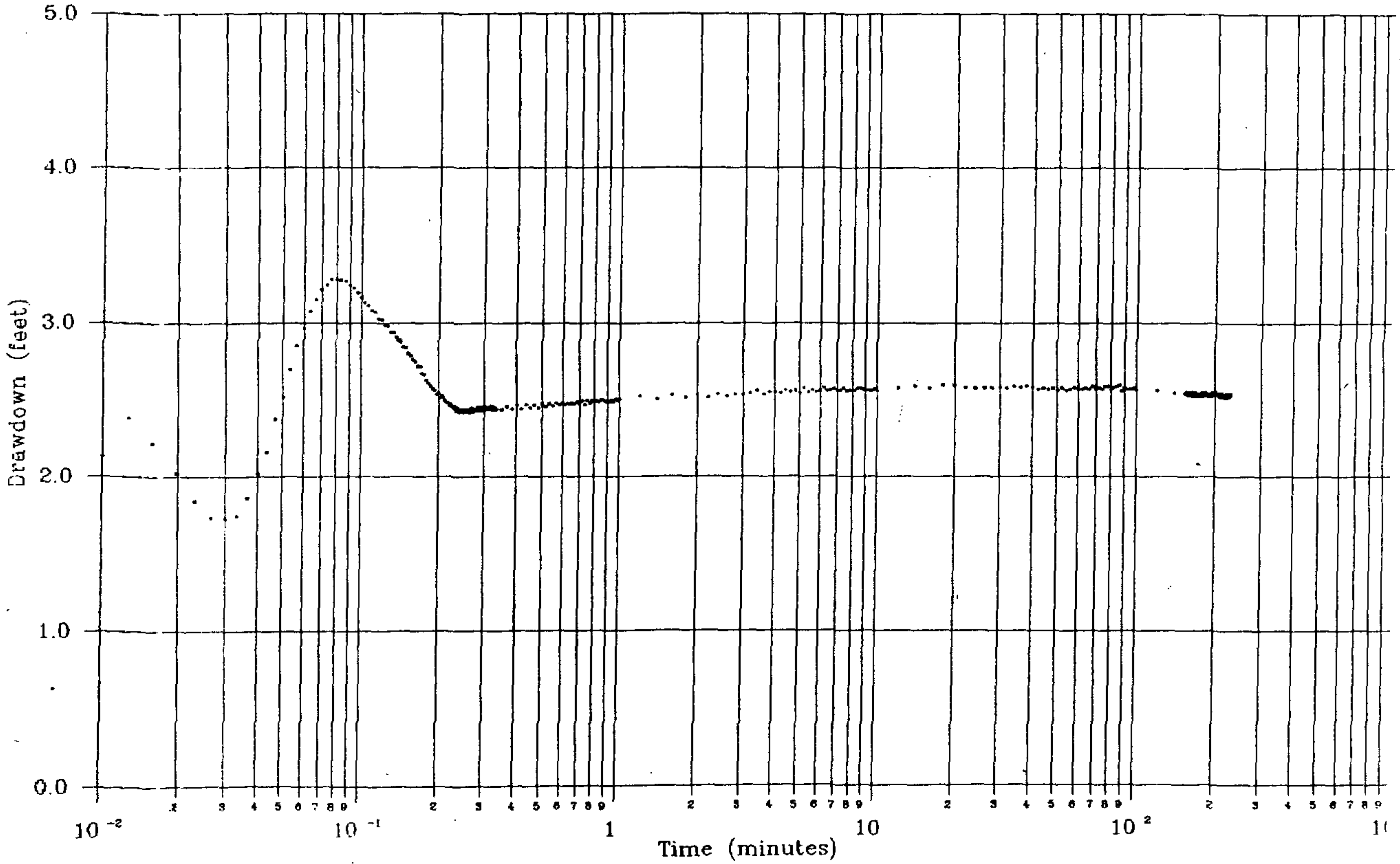
Two transducers set at different levels had to be used in order to collect information as the static water level had risen approximately 50 feet since the time the well was completed. The available transducers could only measure up to 50 feet of head above the probe. The second transducer was set at 70 feet from the top of the casing.

The pump test was started at 11:44 on August 19, 1993 and ended at 13:16 (92 minutes). The flow rate was adjusted to approximately 1.8 gpm. Water-level measurements were recorded by the datalogger at the same intervals as used on MW-11. Recovery was slow (8 hours for 86 percent).

Pumping Well: MW11
Pumptest: Q at 660 gpm
Date/Start of Test: 6/17/93; 16:07:10

PUMP TEST AT 660 gpm
For Pumping Well MW11

001-02
KJZ
File Name: MW11P1SL.GRF
Date Created: 08/24/93



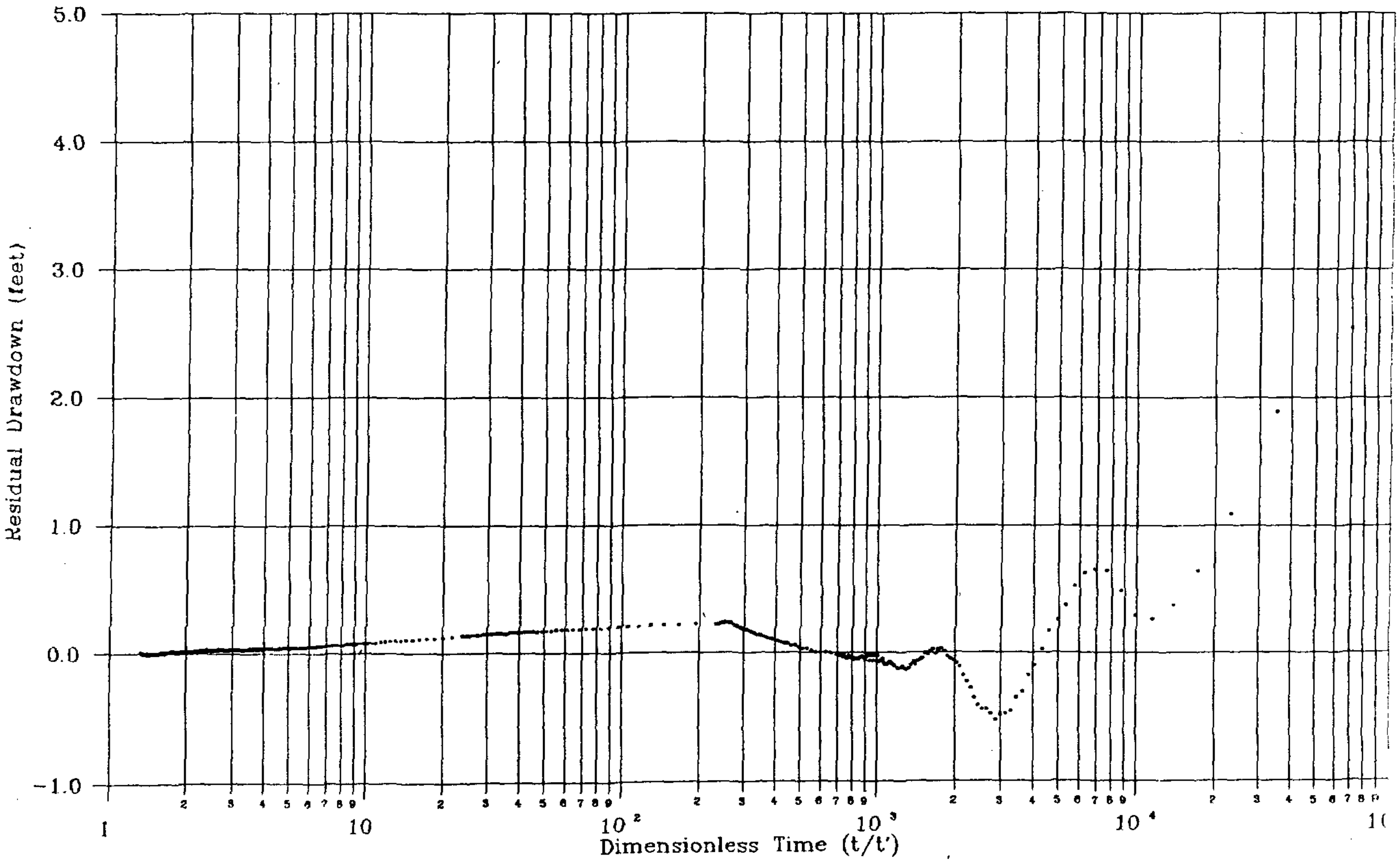
150080

000365

Pumping Well: MW11
Pumptest: Q at 660 gpm
Date/Start of Test: 08/17/93: 18:07:10
Date/Time When Pumping Stopped: 08/17/93 19:57:11

RECOVERY FROM PUMP TEST AT 660 gpm
For Pumping Well MW11

001-02
RJZ
File Name: MW11PR1GRF
Date Created: 08/24/93



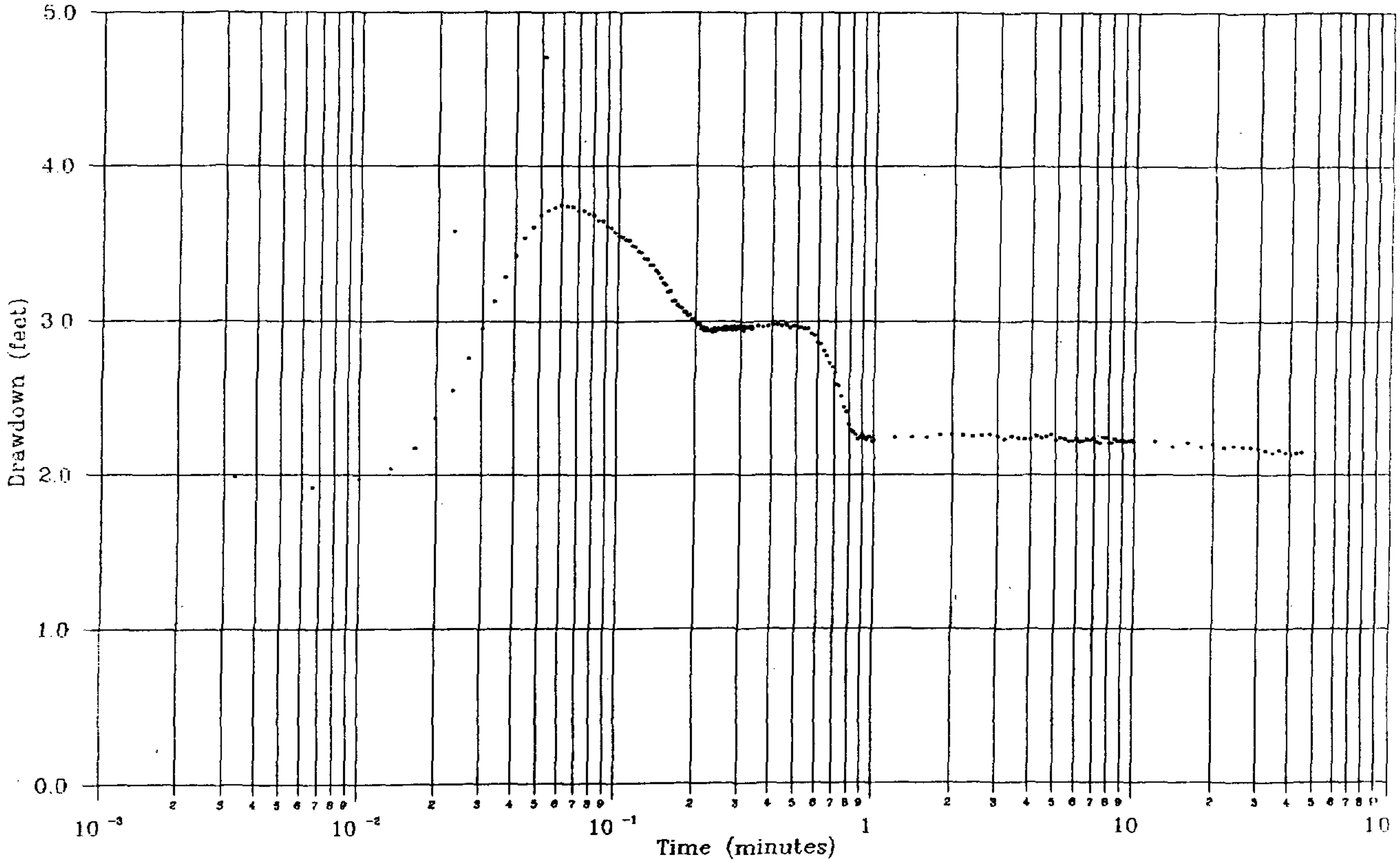
150081

000366

Pumping Well: MW11
Pumptest: Q at 530 gpm
Date/Start of Test: 08/17/93; 11:28:56

STEP TEST AT 530 gpm
For Pumping Well MW11

001-02
KJZ
File Name: MW11S1SLGRF
Date Created: 08/24/93



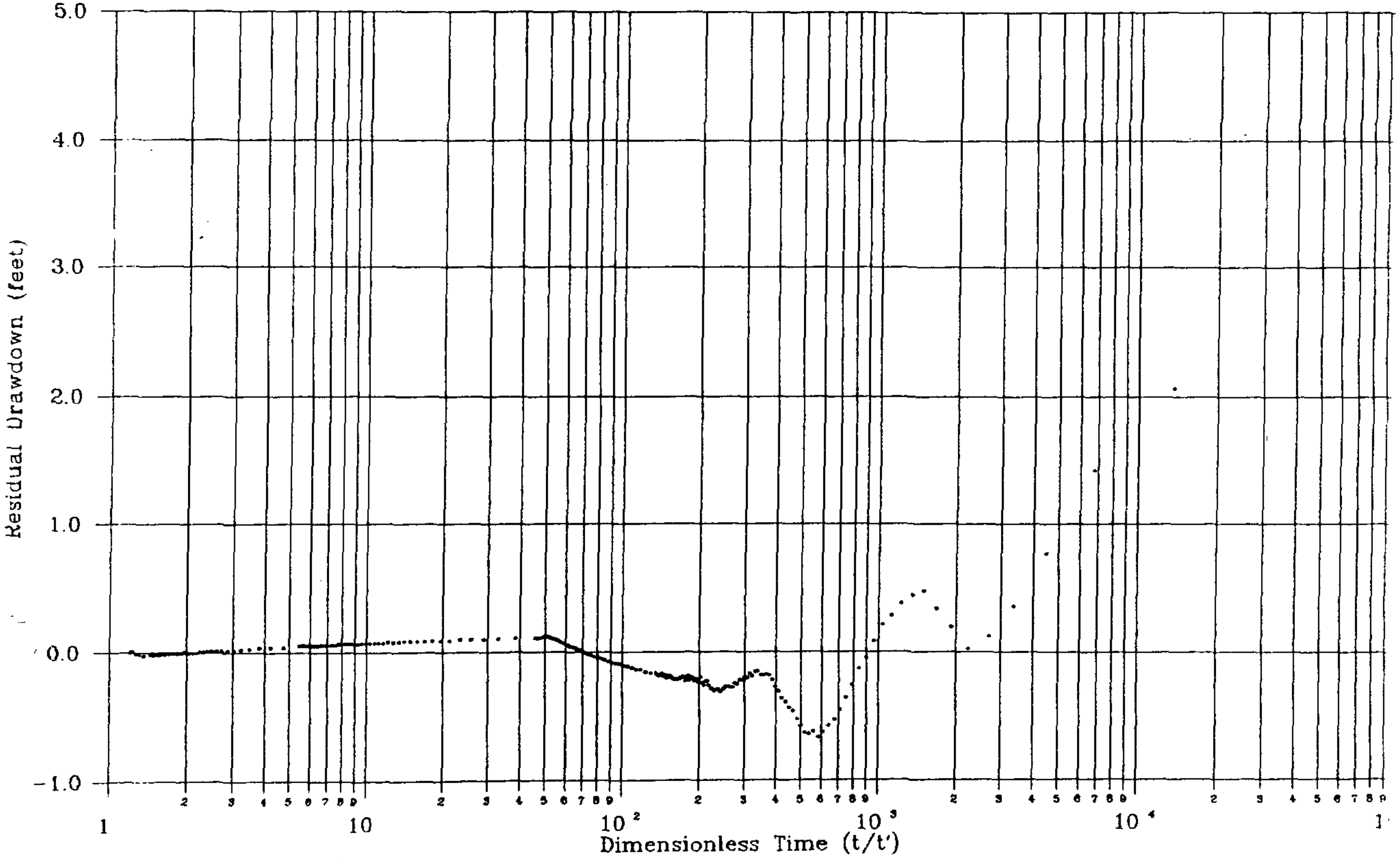
150082

000367

Pumping Well: MW11
Pumptest: Q at 530 gpm
Date/Start of Test: 03/17/93; 11:28:56
Date/Time When Pumping Stopped: 06/17/93; 12:13:45

RECOVERY FROM STEP TEST AT 530 gpm
For Pumping Well MW11

001-02
KJZ
File Name: MW11SR1.GRF
Date Created: 08/24/93



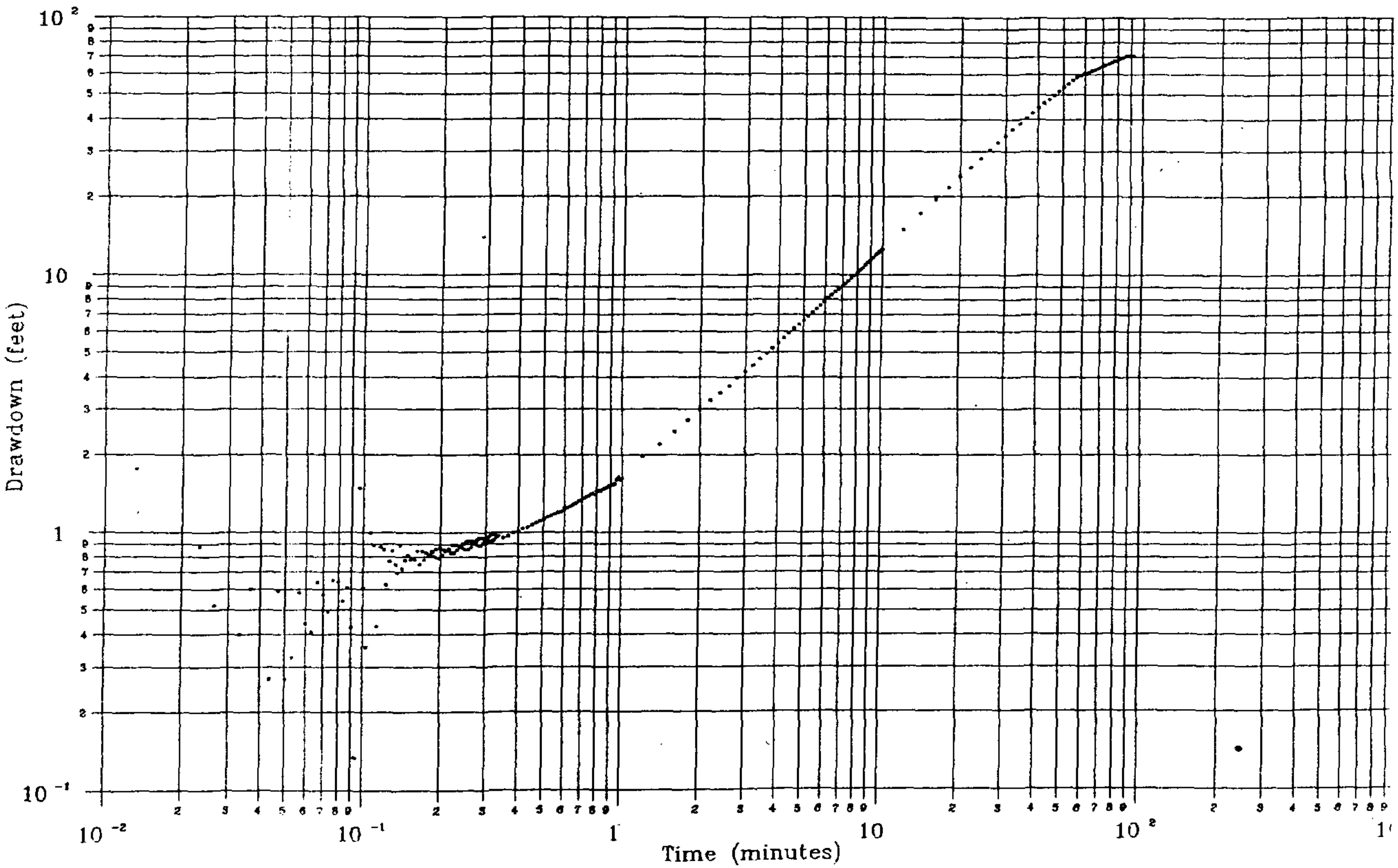
150083

000368

Pumping Well: MW10
Pumptest: Q at 2 gpm
Date/Start of Test: 08/10/93: 11:44:51

PUMP TEST AT 2 gpm
For Pumping Well MW10

001-02
KJZ
File Name: MW10P.GRF
Date Created: 08/24/93

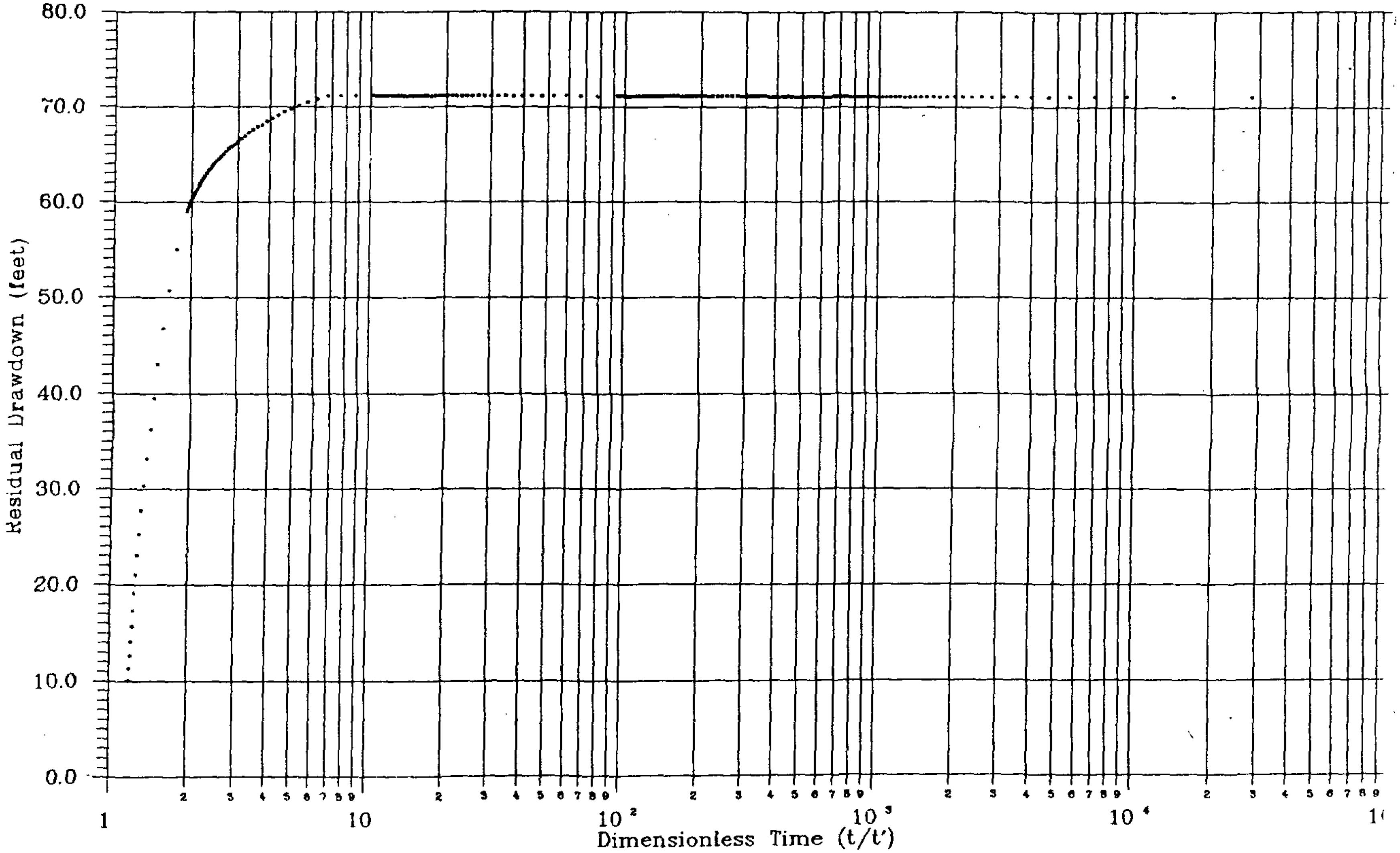


150084

Pumping Well: MW10
Pumptest: Q at 2 gpm
Date/Start of Test: 08/19/93; 11:44:51
Date/Time When Pumping Stopped: 08/19/93; 13:10:58

RECOVERY FROM PUMP TEST AT 2 gpm
For Pumping Well MW10

001-02
K/Z
File Name: MW10FR1.GRF
Date Created: 08/24/93



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000370

APPENDIX E

Drilling and Construction

of Monitor Wells

APPENDIX E

DRILLING AND CONSTRUCTION OF MONITOR WELLS

Drilling

A Gardner Denver 15W drill rig was used to drill the monitor wells at the Molycorp Questa tailings ponds in June and July 1993. This drill rig was outfitted with an air rotary casing hammer which was used to drive 11¾-inch and 9⅝-inch drive casing to prevent unstable formations from caving into the borehole. Upon completion of well drilling/well construction, the drive casing was extracted from the borehole with a hydraulic jacking system.

Well Construction

Monitor wells were constructed of 2-inch and 6-inch Schedule 40 PVC flush-threaded well casing with factory slotted 020 screens. Monitor well MW-11 was completed with 8-inch schedule 80 PVC flush-threaded well casing and screen. MW-11 has a screen filter pack of ⅜-inch silica gravel. All other monitor wells drilled at this time were constructed with 10/20-mesh Colorado silica sand. Bentonite chips (⅛-inch to ⅜-inch) were used as a seal on top of the sand/gravel filter pack.

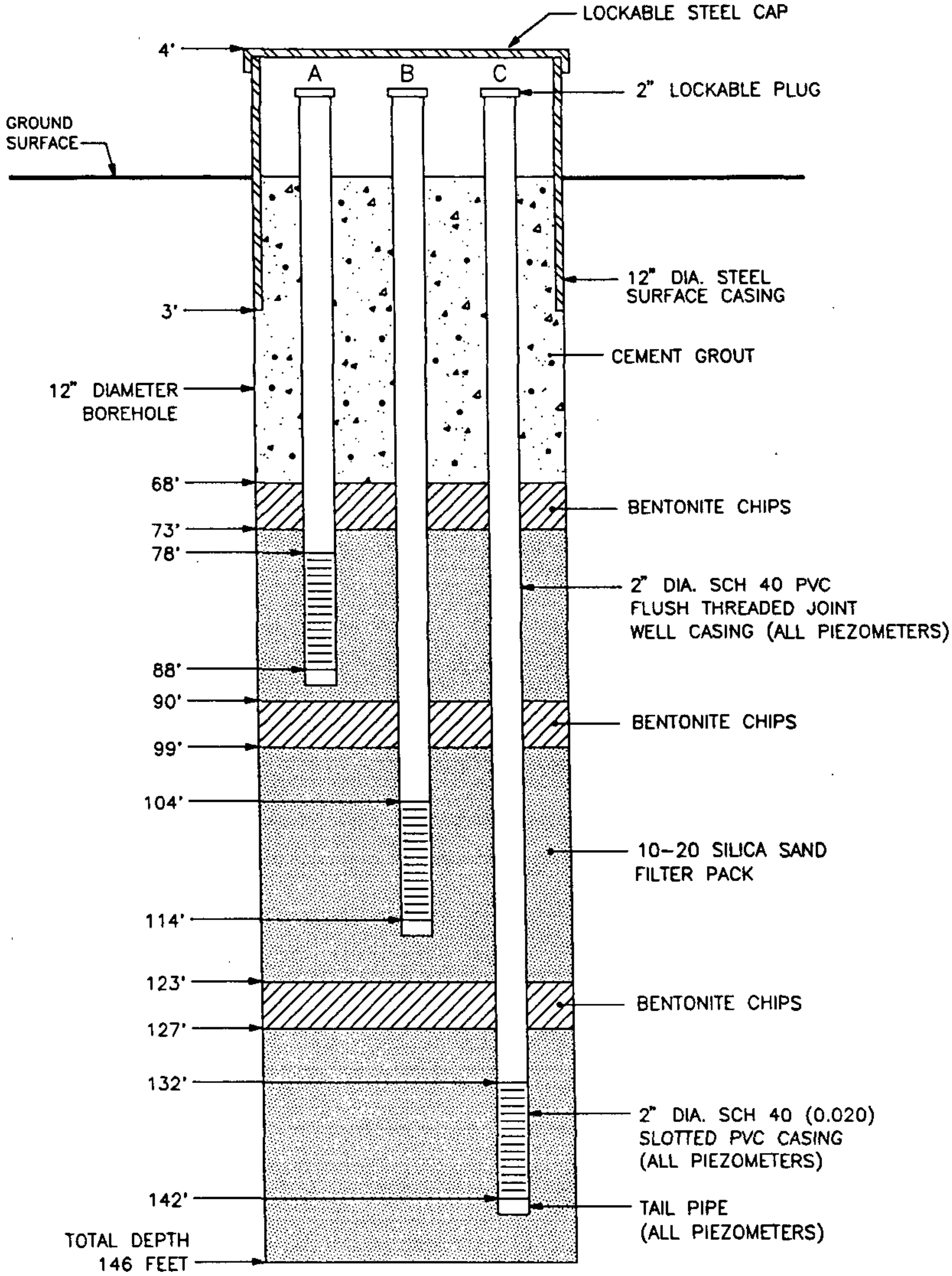
Wells were cemented to the surface. Cement was mixed into a suitable slurry and then pressure-pumped down a 1-inch steel tremie pipe. The driver casing was extracted from each borehole as cementing operations proceeded. Maintenance of the extracted drive casing at approximately 5 feet above the cementing zone helped to prevent borehole collapse. A 3-foot stickup, protected by an upright traffic-visible lockable well vault, was constructed.

Well Development and Logging

The 2-inch piezometer wells were developed by bailing for a period of 4 hours. The 6-inch and 8-inch wells were developed by air-lift for a period of 4 hours.

Cuttings were collected at the cyclone outlet and described for each 10-foot interval. Return water samples were collected in a plastic cup and, after 10 minutes for settling, measured for Ph, conductivity, and Total Dissolved Solids. Water samples were taken from moist zones above static water levels as well as below static levels. Variations in the amount of foaming agent used during drilling, variations in the amount of water discharged to the borehole from the formation, and the frequent instability of the field meters in muddy solutions caused highly erratic readings. The results of these field measurements were considered too unreliable to use as indicators of water quality.

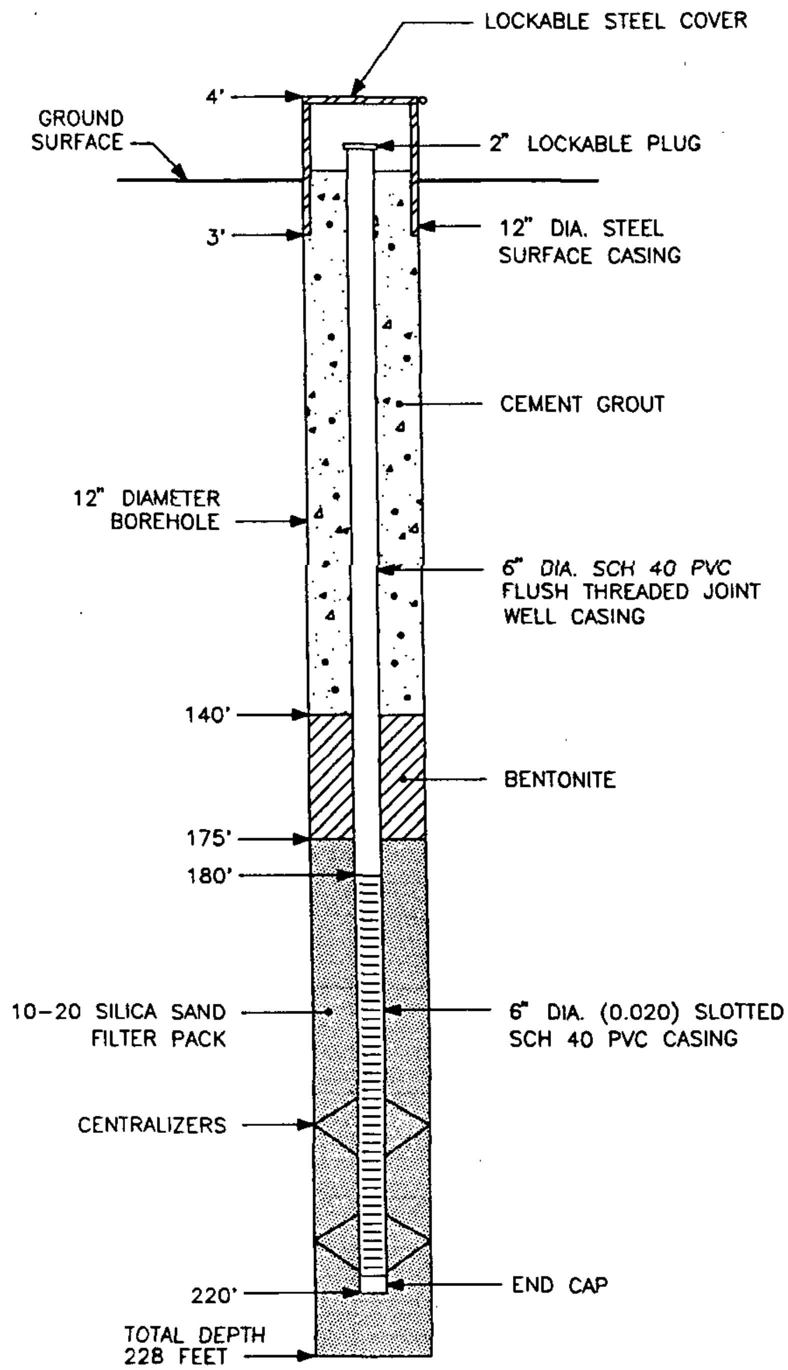
SCHEMATIC OF WELL CONSTRUCTION



NOT TO SCALE

SOUTH PASS RESOURCES, Inc.				WELL CONSTRUCTION MW-7 A,B,C Molycorp, Inc. Questa, New Mexico 150088	FIGURE: E1
PROJECT No.: 001-02	DATE: 9-22-93	AUTHOR: JCA	DRAWN BY: M.O'M.		

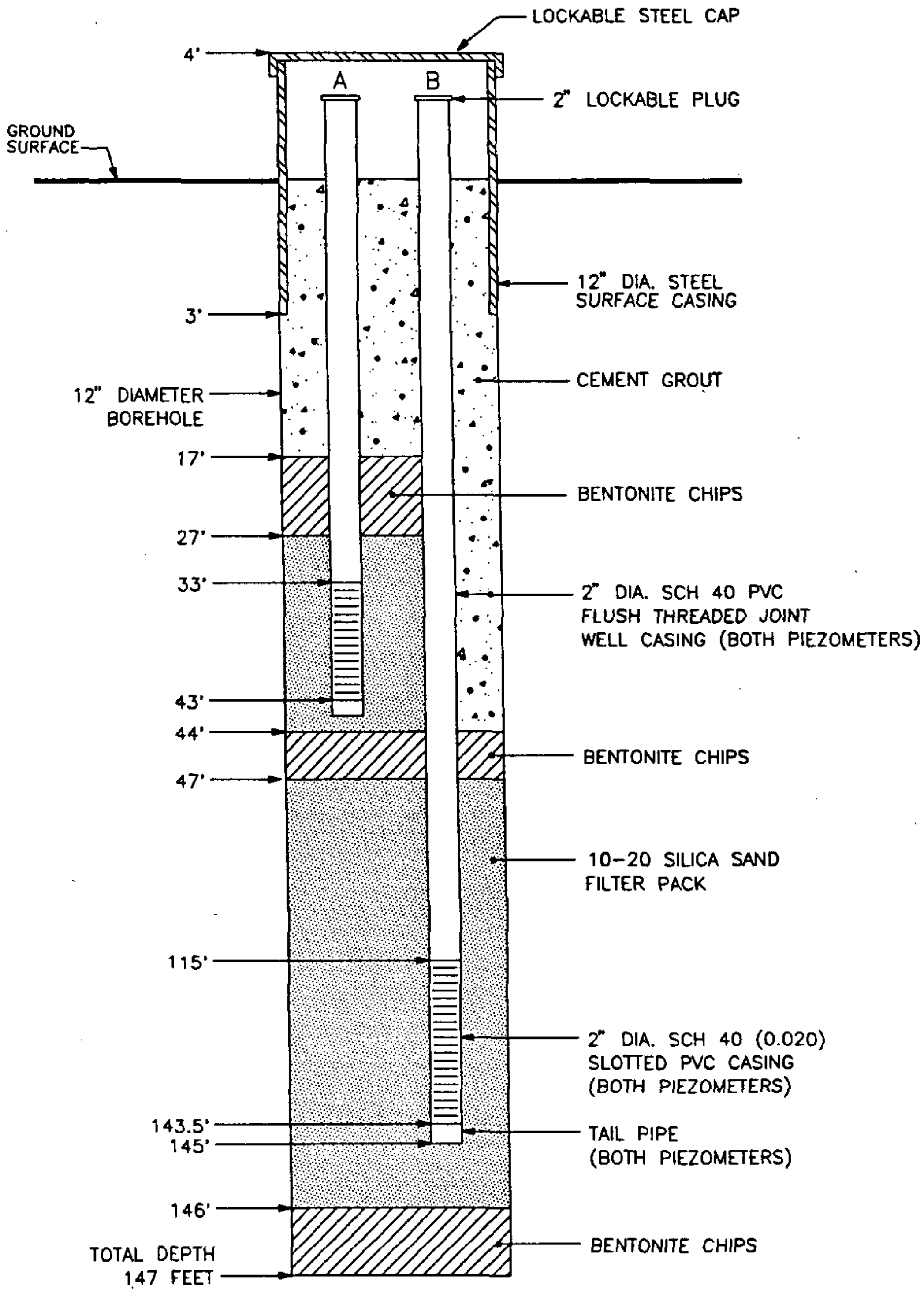
SCHEMATIC OF WELL CONSTRUCTION



NOT TO SCALE

SOUTH PASS RESOURCES, Inc.				WELL CONSTRUCTION DETAIL MW-8	FIGURE:
PROJECT No.: 001-02	DATE: 9-22-93	AUTHOR: [signature]	DRAWN BY: M.O'M.	Molycorp, Inc. Questa, New Mexico 150089	E2

SCHEMATIC OF WELL CONSTRUCTION

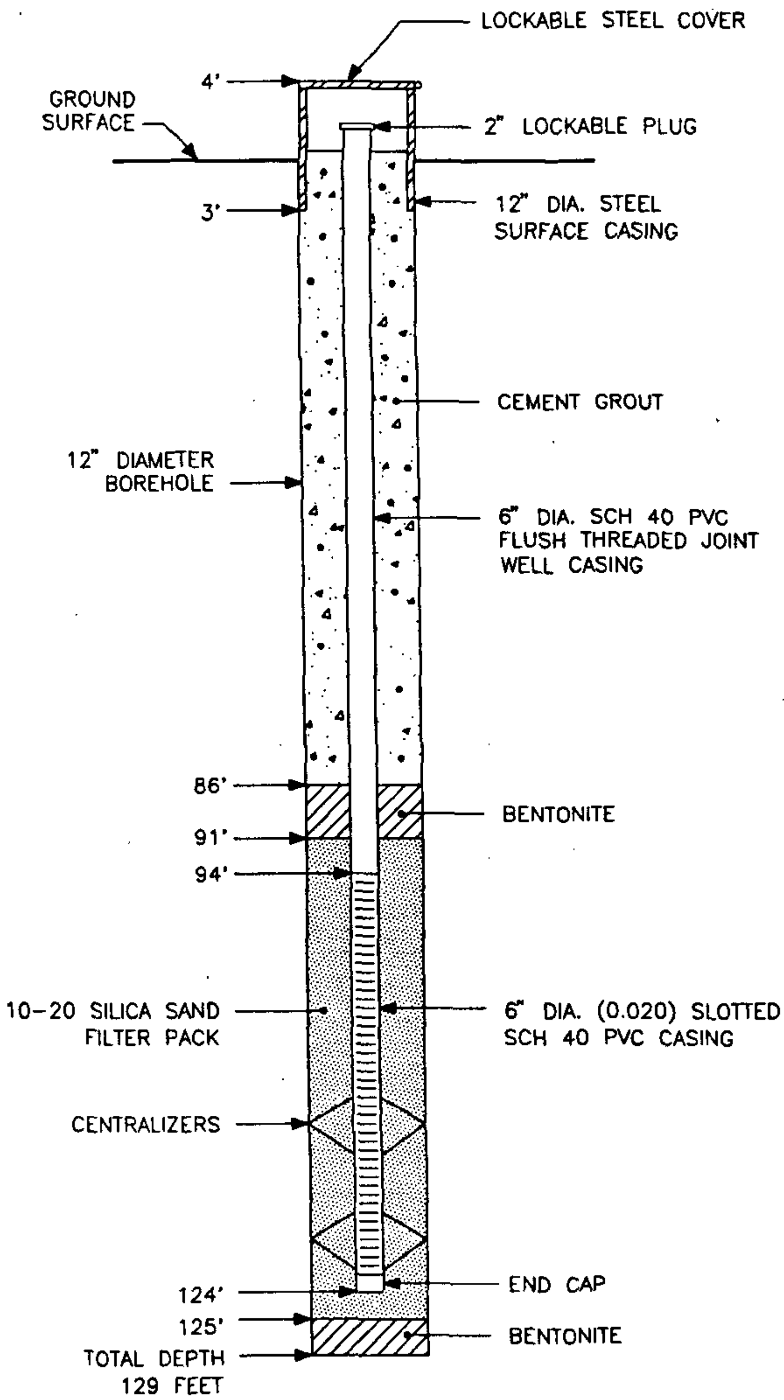


NOT TO SCALE

SOUTH PASS RESOURCES, Inc.				WELL CONSTRUCTION MW-9 A,B	FIGURE:
PROJECT No.: 001-02	DATE: 9-22-93	AUTHOR: [signature]	DRAWN BY: M.O'M.	Molycorp, Inc. Questa, New Mexico 150090	E3

000375

SCHEMATIC OF WELL CONSTRUCTION

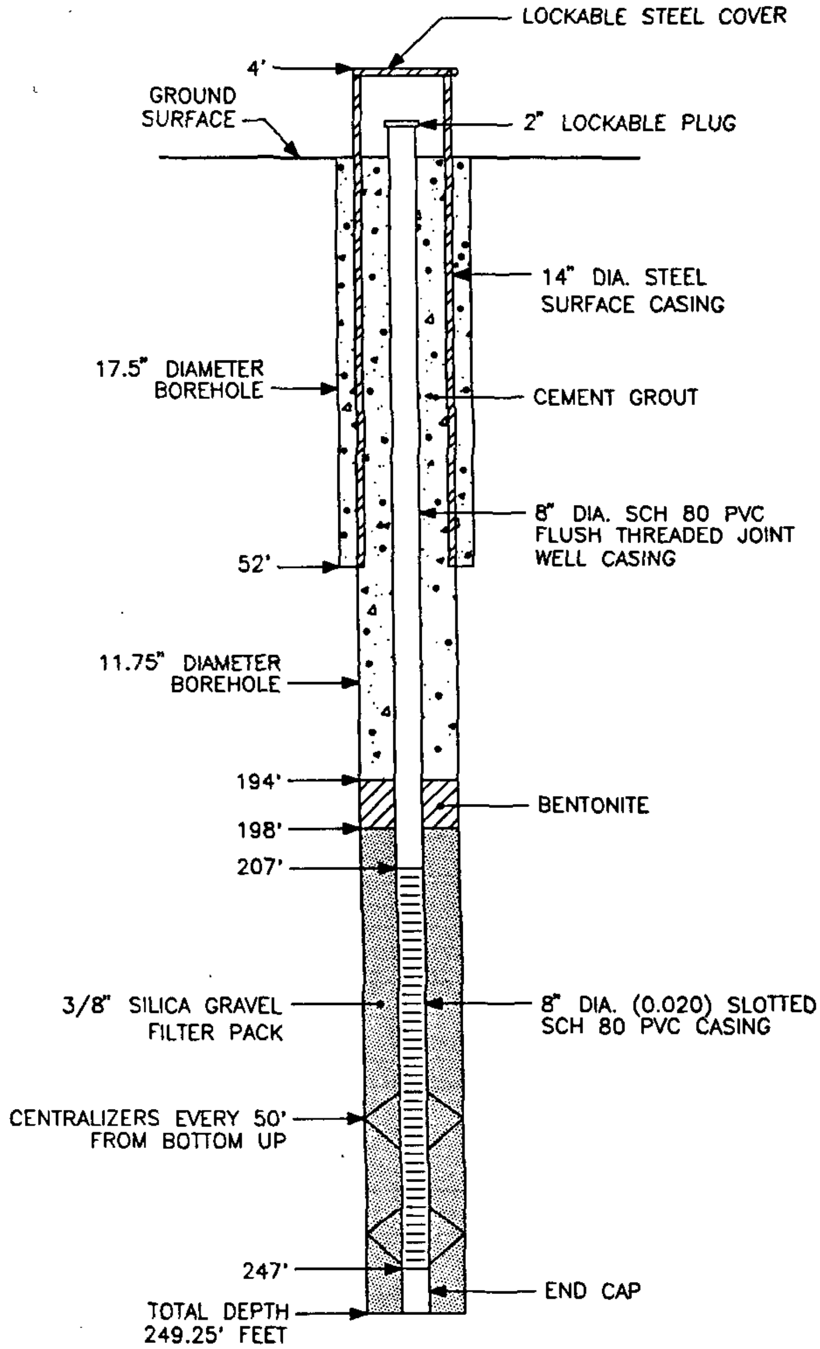


NOT TO SCALE

SOUTH PASS RESOURCES, Inc.				WELL CONSTRUCTION DETAIL MW-10 Molycorp, Inc. Questa, New Mexico 150091	FIGURE: E4
PROJECT No.: 001-02	DATE: 9-22-93	AUTHOR: [signature]	DRAWN BY: M.O'M.		

000376

SCHEMATIC OF WELL CONSTRUCTION



NOT TO SCALE

SOUTH PASS RESOURCES, Inc.				WELL CONSTRUCTION DETAIL MW-11	FIGURE:
PROJECT No.: 001-02	DATE: 9-22-93	AUTHOR: [signature]	DRAWN BY: M.O'M.	Molycorp, Inc. Questa, New Mexico 150092	E5